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Physical Activity in Underserved Preadolescent Youth: Characterization of Accumulation and Patterns and Examination of Socio-Environmental Factors

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Physical Activity in Underserved Preadolescent Youth: Characterization of Accumulation and Patterns and Examination of Socio-Environmental Factors

A dissertation submitted in partial satisfaction of the requirements for the degree Doctor of Philosophy

in

Public Health (Global Health)

by

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2022

The dissertation of Alma Isabel Behar is approved, and it is acceptable in quality and form for publication on microfilm and electronically.

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Chair

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2022

DEDICATION

I dedicate this dissertation to my husband, Benito, who has been a constant source of support and encouragement during the challenges of graduate school and life, and to my son, Andrés, for his unconditional love, patience, and unwavering belief that I can achieve so much. Thank you both for being there every step in the way. I am truly blessed for having you in my life.

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ABSTRACT OF THE DISSERTATION

Physical Activity in Underserved Preadolescent Youth: Characterization of Accumulation and Patterns and Examination of Socio-Environmental Factors

by

Alma Isabel Behar

Doctor of Philosophy in Public Health (Global Health)

University of California San Diego, 2022
San Diego State University, 2022

Professor Noe C. Crespo, Chair

Background: The increasing rates of physical inactivity and sedentary behaviors in youth (ages 6-17 years) are a significant public health concern. Physical activity (PA) levels decline with age starting in preadolescence, with marked disparities among underserved (racial/ethnic minority, low-income) youth, particularly girls. Factors within the social and physical environments appear to influence youth PA, but few studies have investigated their potential impact on accelerometer-measured activity of underserved youth.

Purpose: This study examines how multi-level factors (*individual*: age, sex, BMI; *social*: transportation support; *environmental*: neighborhood characteristics) interact to influence a continuum of accelerometer-measured youth activity behaviors.

Methods: Participants wore an accelerometer for 7 days. PA levels were classified as sedentary (<50 mg), light (50-150 mg), moderate (>150-500 mg), vigorous (>500mg), and MVPA (≥150 mg). Average daily minutes spent in PA and sedentary behaviors during waking time, the prevalence of meeting MVPA guidelines, and PA volume were estimated from accelerometer data. Three-way between-groups multivariate analysis of variance examined adjusted differences between age, sex, and weight status groups across activity outcomes. Main moderation analyses explored the effects of parent-perceived neighborhood environment and child BMI percentile in the relationship between transportation support and total child PA.

Results: Participants (N=68, M_{age}= 9.2 years) spent an average of 103 minutes/day in MVPA and 50% of participants met MVPA guidelines. Youth engaged in more overall PA ($p < .001$) on weekdays than weekends. Participants were also highly sedentary, spending 65% of their waking time at a sedentary level. Older participants spent significantly more time in sedentary behavior ($p < .01$) and had lower PA volume ($p < .01$) than younger participants. Girls spent significantly more time in bouted MVPA ($p < .01$) and had higher PA volume ($p = .01$) than boys. Parent-perceived neighborhood environment ($p = .02$), not transportation support ($p = .91$), influenced total PA. The relationship between transportation support and total PA was not moderated by neighborhood environment nor child BMI.

Conclusions: This study adds to the limited literature available on raw accelerometer data of underserved youth in the U.S. More research is needed to understand the underlying causes of PA and sedentary behavior patterns found in this study.

INTRODUCTION

Youth physical activity (PA) plays a critical role in the prevention of short-term and long-term health outcomes, such as overweight/obesity, metabolic syndrome, diabetes, and cardiovascular disease.[1-3] Yet, the majority of youth (ages of 6-17 years) are considered insufficiently physically active.[4,5] Presently, only 24% of youth meet current guidelines of 60 minutes or more of daily PA,[6,7] with sedentary behavior making up a substantial portion (between 50-60%) of their waking day.[7,8] Youth PA levels decrease with age starting in preadolescence (between ages 9-12 years),[5,9] with lower PA levels found among girls compared to boys,[10] and among youth with overweight/obesity compared to those with healthy weight.[11,12] The greatest disparities in PA, however, are experienced by racial/ethnic minority youth from low-income backgrounds (i.e., underserved youth),[13-15] placing them at increased risk of chronic diseases[1] and other poor health outcomes due to varying combinations of low socioeconomic status and lack of access to services and facilities for PA.[16-18]

The field of PA research has made important strides in identifying correlates of youth PA, but more work is needed to understand the specific mechanisms underpinning the PA behaviors of underserved youth. Increasing evidence suggests that factors within the social and physical environments, such as parental support and neighborhood environment, influence youth PA and sedentary behaviors.[19-23] However, few studies have focused on the specific influence of parent transportation support for PA,[24] and it is not clear if other factors play a role in parents' decisions to support their child's PA participation (e.g., youth weight status, perceived neighborhood safety). Further, few studies use objective measures of youth PA[25] and even fewer studies focus specifically on underserved youth.[26]

Dissertation Overview

Understanding the accumulation and patterns of objectively-measured PA behaviors, as well as the specific socio-environmental factors that influence these behaviors, will help inform public health efforts aimed at increasing PA and decreasing disparities in PA-related health outcomes among underserved youth. This dissertation consists of a single study to characterize accumulation and patterns of accelerometer-measured activity and assess the role of socio-environmental factors on PA and sedentary behaviors of underserved preadolescent youth ages 6-11 years. This research is a secondary analysis of data from a 12-week community-based, family-centered behavioral intervention (Athletes for Life) among 137 parent-child dyads in an underserved region in Arizona.

Specific Aims and Hypotheses

Aim 1: Characterize and compare accumulation and patterns of accelerometer-measured PA by child demographic characteristics. (1a) Assess PA volume (acceleration), accumulation (minutes), average daily PA (minutes), and time spent in intensity levels (sedentary, light, moderate, vigorous). (1b) Evaluate PA variations by weekday versus weekend. (1c) Estimate the proportion of children meeting recommended PA guidelines (≥ 60 min each day). (1d) Examine differences in PA by child age, sex, and weight status.

> H_{1a}: Children will be insufficiently physically active, spending most time at lower activity intensity levels.
>
> H_{1b}: Children will be less active on weekends compared to weekdays.
>
> H_{1c}: The majority of children will not meet recommended PA guidelines.
>
> H_{1d}: Younger children will be more active than older children, boys will be more active than girls, and children with overweight/obesity will be less active than children with healthy weight.

Aim 2: Assess the influence of social- and environmental-level factors on total child PA (mean mins/day). (2a) Assess the extent of parental provision of transportation for PA and examine differences by child age, sex, and BMI status. (2b) Investigate the relationship between transportation support and total child PA and examine if this relationship varies depending on child age, sex, and BMI. (2c) Assess parent-perceived neighborhood environment and examine if neighborhood factors (e.g., infrastructure, aesthetics, safety) are associated with transportation support. (2d) Explore if parent-perceived neighborhood environment and child BMI moderate the relationship between transportation support and total child PA.

H_{2a}: Parents will report greater transportation support for PA among younger children and among boys.

H_{2b}: Transportation support will be positively associated with their children's total PA, and this association will differ by child age and sex.

H_{2c}: A more favorable neighborhood environment will be positively associated with parent transportation support for PA.

H_{2d}: The relationship between transportation support and total child PA will vary depending on parent-perceived neighborhood environment and child BMI.

Exploratory Aim: Explore the influence of social- and environmental-level factors on additional child PA outcomes: Sedentary time (mean mins/day), light PA (mean mins/day), total MVPA (mean mins/day), 1-, 5-, and 10-minute MVPA bouts (mean mins/day), and PA volume (mean mg/day).

Literature Review

Physical Activity: Characterization and Measurement

Physical activity (PA) refers to any body movement that raises energy expenditure above resting metabolic rate (i.e., metabolic equivalent of task, MET). PA is a complex, multidimensional behavior[27] characterized by intensity (how hard an individual works to do the activity), frequency (how often an individual does the activity), and duration (how long a person does an activity in any one session).[7,28] Rates of energy expenditure during PA are commonly described as light, moderate, or vigorous intensity,[7] with activities of a higher intensity requiring more energy (i.e., METs). Sedentary behaviors generally refer to any low-energy waking behaviors characterized by an MET less than or equal to 1.5 (e.g., sitting, reclining, lying down, television viewing, reading, motorized transport).[8,29] Light intensity activity refers to non-sedentary waking behavior characterized by an energy expenditure less than 3.0 METs (e.g., walking at a leisurely pace, doing light household chores). Moderate intensity activities, such as taking a brisk walk or riding a bicycle on level ground, require 3.0 to less than 6.0 METs. And vigorous intensity activities require 6.0 METs or more, for instance jogging, swimming laps, playing basketball, or participating in a strenuous fitness class.[7]

Self-reported activity measures have been widely used in PA research[6,30] as they are a low-cost and convenient method (e.g., survey-based) for assessing PA behaviors. However, self-reported data may be biased, as parents can overestimate their children's activity.[31] Studies measuring youth-reported PA also risk potential recall bias as youth may not remember just how much PA they normally engage or participate in. Most importantly, however, self-reports do not provide accurate estimates of the absolute amount of PA,[32] limiting our understanding of how active an individual or population is.[33] This is especially important for the measurement of PA in children and adolescents, which is generally done in sporadic episodes rather than continuously.[34,35] Objective measures of PA, such as accelerometers, overcome the biases and limitations of self-report PA measures.

Accelerometers provide objective, time-stamped data on PA intensity, frequency, and duration with low participant burden, and have demonstrated high technical reliability in distinguishing activity behaviors (e.g., intensity levels) from inactivity behaviors (e.g., sleep, sedentary time) in youth.[36-39] An additional advantage of using accelerometers includes recent advances in measurement techniques which provide added information to the conventional PA variables obtained from other objective measures, such as pedometers (e.g., bout lengths, PA volume), which is especially useful for describing youth PA profiles.[40-44] PA bouts provide information on episodes of sustained activity of a specified minimum duration and intensity.[34] PA volume (i.e., average magnitude of dynamic acceleration) takes the frequency, intensity, and duration of periods of activity and summarizes them into a single metric representing the accumulated volume of activity within a 24-hour period.[42,45-47] As such, accelerometers are increasingly being used in epidemiological and clinical research to assess youth PA and sedentary behaviors, including evaluating activity levels for population level surveillance,[11,39,48-52] investigating associations between PA behaviors and measures of health and disease,[17,53-57] and examining the efficacy of PA promotion and chronic disease prevention efforts.[58-61]

Prevalence of Youth Physical Activity and Sedentary Behaviors

The U.S. Department of Health and Human Services and the World Health Organization (WHO) currently recommend that youth ages 6-17 years accumulate 60 minutes or more of moderate-to-vigorous activity (MVPA) per day.[7,62] However, the majority of youth do not meet these recommendations (i.e., physically inactive).[4,7,63] A study of the 2009-2019 cycles of Youth Risk Behavior Survey data found that less than 24% of U.S. youth participate in 60 minutes of PA every day.[6] Another study looking at nationally representative data from the National Survey of Children's Health (NSCH) recently found that the prevalence of daily PA among youth decreased significantly from 24% in 2016 to

19% in 2020.[64] And recent studies have found that youth PA prevalence decreased even more during the COVID-19 pandemic.[13,65,66] A study among 5,153 U.S. adolescents (ages 10-14 years) found that the percentage of youth meeting MVPA guidelines decreased from 16.1% (pre-pandemic) to about 8% during the pandemic.[13]

In addition to declines in PA, current prevalence estimates point to rapid increases in youth sedentary behavior overall and in specific sub-domains (e.g., screen time, computer usage for leisure). Data from the 2003-2015 Youth Risk Behavior Survey (YRBS) found upward trends in total hours accumulated in sedentary behaviors, with an increase in screen-based sedentary behavior (e.g., computer use, screen use from mobile devices).[67] Specifically, the prevalence of sedentary behavior involving computer usage increased from 22.1% in 2003 to 46.1% in 2019.[68] Research also indicates that youth spent the majority of their waking time in sedentary behavior. A large study in a representative sample of 6-17-year-old youth in the U.S. recently found that youth spent 52% of their waking day being sedentary, spending slightly less time in light intensity PA (45% of the time), and spending less than 4% of their time in MVPA.[16] Data from the 2002-2004 National Health and Nutrition Examination Survey (NHANES) showed that preadolescent youth spent an average of 6 hours per day in sedentary behaviors.[9] However, more recent estimates suggest that youth now spend an average of 6.6 to 8.6 hours per day in sedentary behavior and/or recreational screen time.[8,69]

Unlike current PA recommendations, however, there are no existing guidelines in the U.S. for sedentary behaviors in children and adolescents. PA objectives for *Healthy People 2020* included decreasing the proportion of youth who view television, play video games, or use a computer for non-school work for more than 2 hours per day, although this objective was no longer part of the more recent *Healthy People 2030* aims.[70] Nonetheless, recommendations by the World Health Organization continue to advise that youth limit the amount of time spent being sedentary, particularly the amount of time spent in recreational (non-school work related) screen time.[62] Yet, nationwide data point to an increase in sedentary-based screen time among U.S. youth. Data from the 2007-2012 NHANES cycle showed that 38% of adolescents (ages 12-19 years) spent > 2 hours/day watching television and 22% spent > 2 hours/day using a computer.[69] Data from the 2015-2016 NHANES cycle revealed that the majority of youth between the ages of 6 and 19 years engaged in more than 2 hours/day in screen time.[5] And the most recent national data from the 2017 Youth Risk Behavior Survey estimate that 43% of adolescent students (grades 9-12) spent > 3 hours/day playing video/computer games or using the computer for non-school work.[71] Further, a recent study in a demographically diverse national sample of 5,412 youth (ages 10-14 years) found that mean total daily screen use increased significantly during the COVID-19 pandemic.[72] Adolescents reported an average of 7.7 hours/day of screen use, which is higher than pre-pandemic estimates (3.8 hours/day) from the same cohort at baseline.[72]

Sedentary behavior has more recently been studied as a separate construct from physical inactivity, with research showing that PA and sedentary behaviors are not the opposite of each other.[73,74] Research studies suggest that, although youth who meet PA guidelines are considered physically active, this does not preclude them from also accumulating a significant amount of time in sedentary behaviors. That is, youth can be categorized as both sufficiently active and excessively sedentary.[1,73] A study in a sample of 826 preadolescent youth in Ireland found that children accumulated 90.6 minutes/day of MVPA, which represented 10.8% of their waking time. However, children in this sample also spent 61.3% of their waking time being sedentary (approximately 8.9 hours/day).[75] Another study in Denmark among 902 youth ages 5-12 years found that participants engaged in 59.9 minutes/day of MVPA while spending almost 9 hours/day being sedentary.[76] A study by Antczak and colleagues with 1,059 Australian youth ages 8-9 years found that participants spent 7.5 hours/day being sedentary despite accumulating 83.1 minutes/day of MVPA.[36] And a small study with rural Latino families in the U.S. found that, although 100% of children in their sample met PA guidelines, children spent most of their waking time in sedentary behaviors.[77] Participants in this sample spent an average of 175 minutes/day in MVPA and 7.7 hours/day being sedentary.[77]

The prevalence of PA and sedentary behaviors in youth also vary by days of the week. Studies show that youth are generally less physically active and more sedentary on weekend days (Saturday-Sunday) compared to weekdays (Monday-Friday).[75,78-81] Data from a nationally representative sample of children showed that median MVPA on weekdays (47.5 minutes/day) was higher compared to weekend days (35.5 minutes/day).[79] Another study by Brooke and colleagues found that school-aged children accumulated an average of 82 minutes/day of MVPA during weekdays compared to 68 minutes/day over weekend days.[80] And a recent study found that Hispanic/Latino youth were also less active on weekend days compared to weekdays.[81] Further, a cross-sectional study among 1,165 youth (ages 9-18) found that the prevalence of ≥1 hour/day of screen time was 31.2% on a typical school day and 41.6% on a typical weekend day.[82]

Youth Activity and Health

The increasing rates of physical inactivity and sedentary behaviors in youth are a significant public health concern. Youth physical inactivity contributes to the global burden of disease, as it is a significant risk factor for the development of short-term and long-term health outcomes, such as metabolic syndrome, heart disease, overweight/obesity[1,2] and obesity-related cardiometabolic disorders.[83] Evidence supports the numerous benefits of regular PA on child and adolescent health.[1,84] Among youth, PA has been linked to greater cognitive health,[85] decreased adiposity,[16] improved muscle fitness,[86] increased cardiometabolic health[16,87] and positive mental health outcomes.[88] Studies show that high-intensity activities in youth help to reduce the risk for several chronic diseases,[89] with PA of moderate and vigorous intensity positively associated with fitness and cardiometabolic health in youth.[53-55,89,90] As such, public health efforts have primarily focused on the promotion on MVPA in youth.

Research also suggests that the total amount of PA is more important for getting the most health benefits than is any single component (e.g., high intensity PA). For example, total PA (i.e., activity of light, moderate, and vigorous intensities) is positively associated with various physical, psychological, and cognitive health indicators among youth aged 5-17 years.[18] A systematic review and meta-analysis recently found that low-frequency, high-intensity, and short duration PA effectively improves muscle fitness in youth (ages 5-18 years).[86] Additionally, evidence supports that PA -regardless of intensity, frequency, or duration- provides important health benefits.[7] That is, any PA is better than no PA. And research studies indicate that low-frequency (< 3 times/week), high-intensity, and short-duration (< 60 mins per session) PA improves fitness in children and adolescents. In addition to this, PA performed at a light-to-moderate intensity can also help improve muscle strength[86] and cardiometabolic biomarkers[91] in youth. PA recommendations have also traditionally focused on MVPA performed in a continuous manner.[18] However, research supports that both bouted and non-bouted MVPA can improve a variety of health outcomes.[92,93] A recent study in a nationally representative sample of youth ages 6-18 years found that longer continuous bouts of MVPA had beneficial effects on body anthropometrics (e.g., BMI percentile, waist circumference).[35] And another study found that MVPA accrued in bouts predicted adiposity status independent of the total volume of MVPA.[44]

Sedentary behavior has also received an increasing amount of attention as a public health problem, due to the sharp increase in the prevalence of sedentary behavior in youth and the health risks associated with being excessively sedentary. Sedentary behavior, independent from physical inactivity, is associated with increased cardiovascular morbidity and mortality in adults.[94] Less is known about the negative effects of sedentary behaviors in youth, although there is some evidence of associations between increased sedentary-based behavior (screen time, television viewing) and increased waist circumference,[16] decreased cardiorespiratory fitness,[54,95] and increased adiposity.[8,75] Additionally, other metabolic effects of sedentary behavior in youth (e.g., lower insulin sensitivity, metabolic syndrome) were identified in some studies, with health impacts into young adulthood.[8] A recent study also found that youth sedentary behavior was associated with increased depression, anxiety, and other mental health problems later in life.[96]

Disparities in Physical Activity and Sedentary Behaviors among Youth

Adequate PA is an essential component of chronic disease prevention and a healthy lifestyle. However, research points to existing differences in youth PA and sedentary behaviors defined by age, sex, race/ethnicity, and socioeconomic status (SES), placing specific populations at increased risk of PA-related health disparities. Physical inactivity and sedentary behaviors are consistently higher among older (vs. younger) youth, and the proportion of youth meeting PA guidelines decreases with age starting in preadolescence (between ages 9-12 years).[4,5,9,97-99] Roughly 42% of preadolescents meet PA guidelines compared to 7.5% of adolescents ages 12-15 years.[5,100] Younger adolescents (10-12 years) also spend more time in MVPA than older adolescents (12-14 years).[101] And a study by Evenson and colleagues found that, among Mexican-American youth, those aged 6-11 years engaged in more daily MVPA (85 minutes/day), compared to their older counterparts aged 12-15 years (37 minutes/day).[49] Studies also show that increasing age is associated with more screen time.[8] Approximately 35% of youth ages 6-11 years meet screen time recommendations (i.e., 2 hours or less per day) compared to 31% of older youth ages 12-19 years, with about 43% of older adolescents spending more than 3 hours/day using a computer or other electronic device.[5] Further, a recent study by Dunton and colleagues found that, compared to children (ages 5-8 years), preadolescents (ages 9-13 years) spent significantly more time in sedentary behaviors, such as playing computer or video games (64.9 minutes/day vs. 39.0 minutes/day), using the computer for leisure (64.9 minutes/day vs. 17.5 minutes/day), and talking on the phone/texting (26.4 minutes/day vs. 3.4 minutes/day).[65]

Compared to boys, physical inactivity and sedentary behaviors are consistently higher among girls.[10,12,49,102] A recent longitudinal study in a sample of 22,091 youth ages 3-18 years found greater declines in MVPA among girls compared to boys.[103] Data from the 2003-2006 NHANES national study found that MVPA was significantly lower among girls compared to boys,[50] and data from the 2009-2019 Youth Risk Behavior Survey (YRBS) indicate that, among adolescents (grades 9-12), approximately 31% of males and 15% of females met the daily MVPA guidelines.[10] Another study found that 48% of adolescent boys met MVPA guidelines, compared to 24% of adolescent girls.[81] And a study among children ages 8-10 years found that only 5% of girls met MVPA guidelines compared to 28% of boys.[73] Recent studies also suggest that there are sex differences in types of sedentary behaviors.[8,65,69] Compared to boys, girls spend more time sitting, spend more time using the computer for leisure, and have higher screen time (e.g., making video calls, talking on the phone, texting).[65,69] On the other hand, boys spent more time than girls playing computer or video games.[65]

Youth with overweight/obesity also have lower PA levels compared to youth with healthy weight.[12,75,81,102,104] Sanders and colleagues, in a sample of 930, predominantly Hispanic/Latino, adolescents (ages 13-18 years) in New Mexico, found that participants with obesity did significantly less MVPA and vigorous PA compared to participants with health weight.[81] Keane and colleagues found that 26.0% of children with normal weight met current MVPA guidelines, compared to 9.7% of children with overweight/obesity.[75] Youth with overweight/obesity are generally more sedentary overall and report spending more time in screen time use compared to youth with healthy weight.[73] Data from the 2007-2012 NHANES cycle revealed that adolescent males with obesity spent 43 more minutes/day sitting and 12 fewer minutes/day in MVPA compared to their male peers with healthy weight.[69] And data from the NHANES Youth Fitness Survey shows that 6-11-year-old preadolescents who exceeded screen time recommendations (i.e., > 2 hours/day) were 1.69 times more likely to have overweight/obesity compared to those who met screen time recommendations (i.e., < 2 hours/day).[105]

The greatest disparities in PA and sedentary behaviors, however, are experienced by underserved (racial/ethnic minority, low-SES) youth.[12-15,71,106-110] The prevalence of meeting the PA guidelines of at least 60 minutes of daily MVPA is higher among White youth (grades 9-12), compared to Black and Hispanic/Latino youth.[71] NHANES data from the 2007-2012 cycle showed that non-Hispanic white female adolescents participated in more MVPA than females from all other race/ethnicity groups.[69] The prevalence of sedentary-based screen time (i.e., playing video games, using a computer for leisure) is also higher among Black and Hispanic/Latino youth compared to their White peers.[71,111] Hispanic/Latino youth, in particular, engage in low levels of activity that are well below PA recommendations.[12,49] Currently, about 25% of Hispanic/Latino youth meet daily PA guidelines.[6,10] PA decline is also greater among Hispanic/Latino youth (ages 6-19 years), compared to non-Hispanic white youth.[15] This is important as research shows that low levels of PA are associated with an increased prevalence of overweight and obesity among Hispanic/Latino youth,[71,112-114] particularly those ages 6-11 years.[115]

Recent national youth data indicate that only 33.3% of Hispanic/Latino boys and 18.1% of Hispanic/Latino girls meet the daily PA guidelines, compared to 36.7% and 18.4% of their White male and female counterparts, respectively.[71] However, PA also varies between Hispanic/Latino sub-groups. For example, Mexican-American youth (ages 8-16 years) have shown higher levels of MVPA compared to youth of Central American, Cuban, and Dominican backgrounds.[49] Recent national estimates also show that the prevalence of sedentary-based screen time for > 3 hours/day is higher among Hispanic/Latino youth (45.4%) compared to White youth (40.7%).[71] Additionally, over 20% of Hispanic/Latino youth watch television 3 or more hours per day compared to 17% of white youth.[71]

Studies also indicate that youth who are insufficiently active live in homes with the lowest SES, compared to those from higher-SES households, due to varying combinations of low household income and lack of access to low-cost opportunities for PA. A recent population-based cross-sectional study of over 8,300 youth from England and the U.S. (ages of 11-17 years) found significant income-based inequalities in self-reported MVPA.[116] Results from this study show that adolescents from low-income households had lower levels of participation in any formal sports/exercise and in recreational MVPA, compared to those from high-income households.[116] Additionally, underserved youth (ages 10-17 years) accumulate, on average, 749 mins/day in sedentary time (i.e., 12.5 hours/day).[117] Recent research indicates that the current COVID-19 pandemic has also exacerbated PA disparities among underserved youth. A recent study of youth PA during the pandemic found that racial/ethnic minority youth and youth from low-SES backgrounds were less likely to meet MVPA guidelines during the COVID-19 pandemic.[13] As such, underserved youth represent a high-risk group with regard to physical inactivity, sedentary behaviors, and related health outcomes,[112,118] emphasizing the need to improve PA-promoting efforts in this particular population.[26,119,120]

Role of the Social and Physical Environment on Youth Activity

PA is a complex and multi-dimensional behavior, which is determined by numerous biological, psychological, sociocultural, and environmental factors. The field of PA research has made important strides in identifying correlates of youth PA.[14,121,122] Age, sex, and weight status have been consistently identified as strong predictors of child and adolescent PA behaviors. But recent studies also suggest that factors within the social and built environments play an important role in youth PA and sedentary behaviors.[123-125] As such, there has been an increased emphasis on the role of the social environment as a key modifiable determinant of youth PA in recent years. Yet, studies with underserved youth are limited.

Studies have shown that youth's social and physical environments are inextricably linked.[117,123,126-128] Within the social environment, social networks can either support or undermine youth PA behaviors.[129-134] Social networks are believed to operate through four primary pathways: social influence, social engagement, access to resources, and social support.[135] Social support refers to the direct and indirect resources derived from interactions with members of one's social network.[136,137] Within a PA context, social support concerns tasks or steps that significant others (e.g., family, friends) take to facilitate PA behaviors.[138] Support for PA can be tangible -such as instrumental support (e.g., transportation, payment of fees, purchase of equipment)- or intangible, such as emotional (e.g., encouragement) or informational (e.g., discussing benefits).[139]

Parent social support is among the most consistently observed source of influence on youth PA and sedentary behavior, and on activity-related health outcomes.[23,139,140-147] Yet, youth PA is not influenced by family in the same way across varying factors (race/ethnicity, age, sex).[148-151] Hispanic/Latino youth report the lowest parent and family social support,[152] compared to their African American and White counterparts.[153] Hispanic/Latino girls report less social support for PA,[154] compared to African American girls.[155] A longitudinal study by Dishman and colleagues found that girls who reported having strong social support had less of a decline in PA.[156,157] Boys report greater perceived support for PA than girls,[158,159] and parents report providing more support to boys compared to girls.[160] Additionally, research shows that family-provided social support is positively associated with PA in youth with healthy weight, but not in those with overweight/obesity.[161] Furthermore, studies suggest that mothers are important sources of social support for their children's PA,[148] and that parent support appears to be mediated by their child's weight status.[162-164]

Parent support may have an important influence among underserved youth with limited resources for PA.[126,157,165,166] Instrumental support from parents (e.g., getting rides to sporting activities or to other locations for PA) appears to be especially important.[24,143,148,160,167,168] Lack of transportation to and from activities has been identified as an important barrier to participation in PA among low-SES youth.[169] As such, parent transportation support may provide increased opportunities for PA. Generally, youth younger than 15 years depend on parent-provided transportation to participate in activities and be physically active.[158,159] A number of studies have found that parent transportation support is positively associated with youth MVPA.[24,143,148,160,170] Studies also suggest that parental transportation support is also protective against declines in total PA among girls.[171] Thus, recent studies have identified transportation support as a meaningful determinant of youth PA at a national level.[170]

Yet, a limited number of studies have focused on the specific influence of parent transportation support for PA among underserved youth, and it is not clear if other factors play a role in parents' decisions to support their child's PA participation in this specific population. Some studies suggest that parent social support and aspects of the neighborhood social environment (e.g., traffic safety, crime, walkability)[172] may work together to create circumstances where youth PA behaviors are more or less likely to occur.[20,21,126,171,173,174] Recent studies provide evidence of the associations between neighborhood features and youth PA.[175-177] Neighborhood walkability, specifically, has been found to be a strong predictor of objectively-measured PA in adolescents.[174,178-181] There is some evidence that Hispanic/Latino children engage in more PA activity when the quality of the neighborhood social environment is higher.[182] Another study among African-American and Hispanic/Latino adolescents indicates that neighborhood safety concerns are a key barrier to PA, while social support is a key facilitator for PA.[165]

Studies also show that perceived neighborhood safety is associated with PA.[181,183,184] A systematic review of empirical studies that examine associations between neighborhood safety and PA among youth suggests that low levels of youth PA in their neighborhood are associated with a lack of parent-perceived neighborhood safety.[21,185] Traffic safety, in particular, is a key concern for children's safety.[21,186] Since children and adolescents have less autonomy than adults, neighborhood environmental features, as well as parents' perceptions of these features, can play an important role in youth PA participation,[186,187] particularly among underserved youth.[126,188]

For youth with limited financial resources for PA, neighborhood streets may offer opportunities for leisure-time PA (e.g., hiking, walking) and active transport (e.g., walking to/from school).[189] Thus, the presence of pedestrian and cyclist safety structures (e.g., pedestrian crossings, bike lanes, sidewalks) play a significant role in supporting youth PA.[175,179,184,190] There is evidence of positive associations between higher neighborhood economic status and youth physical activity.[108,191,192] However, neighborhood environments that promote PA are often not equitably distributed.[193] Racial/ethnic minority youth from low-income backgrounds face unique challenges to PA,[192] as they experience considerable economic and racial disparities in their neighborhood environments (e.g., unpleasant aesthetics, high crime, traffic hazards).[181,194,195]

Results from the 2018 *U.S. Report Card on Physical Activity for Children and Youth* (ages 6-17 years) revealed significant race/ethnicity differences in neighborhood safety, indicating that 53% of African-American and 54% of Hispanic/Latino youth live in safe environments, compared to 72% of White youth.[5] Lack of neighborhood features that are supportive of PA (e.g., sidewalks, crosswalks) may, therefore, interact with social factors (e.g., perceived crime, perceived traffic safety) to create barriers that reduce potential benefits from activity-supportive neighborhoods.[175] Thus, non-PA-supportive environments can contribute to underserved youth not engaging in outdoor PA, likely exacerbating barriers to PA in this population.[196] This is significant as it places underserved youth at an increased risk of physical inactivity and poor health due to varying combinations of low SES and lack of PA-supportive environments.[192,197,198]

Theoretical Framework

This dissertation is guided by the socioecological model,[199] to examine associations between individual (youth age, sex, BMI), social (parent transportation support for PA), and environmental (perceived neighborhood environment) factors -and interactions between these factors- and a full continuum of accelerometer-measured activity behaviors (i.e., total PA, sedentary behavior, light activity, MVPA, MVPA bouts, PA volume) in underserved youth (**Figure 1**). From a socioecological perspective, people's health-related behaviors are shaped by a collection of intrapersonal-, interpersonal (social)-, and environmental-level influences. The interpersonal level of the socio-ecological framework involves the relationship with other individuals (family) that provide social identity, support, and role definition from two or more settings in which the individual participates (home, school).[200] However, a comprehensive understanding of youth PA and sedentary behaviors must also look at potential interactions between multiple levels of influences to determine if the presence of factors within various levels work together to facilitate health behaviors.[201] Increasing evidence suggests that youth PA and sedentary behaviors are dependent on interacting effects across multiple levels of influence within their social environment.[20,126,172] As such, this study is also underpinned by interpersonal level theories of health behavior[202] and newer social network perspectives, which assume that individuals exist within, and are influenced by, their social environments, specifically through social relationships (e.g., through social support).[135,203]

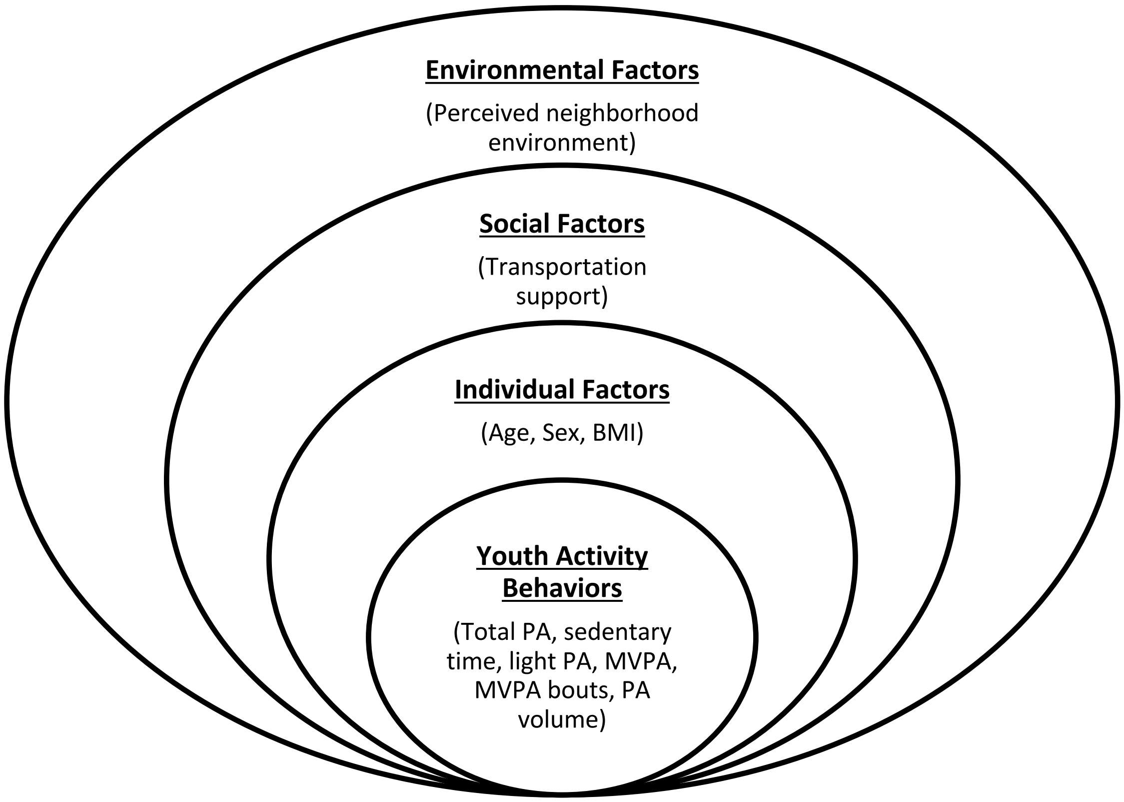

Figure 1: Adapted socioecological model to examine multi-level influences on accelerometer-measured youth PA and sedentary behaviors in underserved preadolescent youth.

METHODS

Study Design and Participants

This study consists of secondary data analyses to evaluate accelerometer-measured PA prevalence and patterns and examine socio-environmental determinants of PA among underserved preadolescent youth. This study utilizes data from the *Athletes for Life* study (AHA 14SDG20490382, NCT03761589), a randomized control trial to test the efficacy of a 12-week, behavioral intervention on parent and child cardiovascular fitness, its primary outcome. Secondary outcomes of the *Athletes for Life* study included accelerometer-measured parent and child PA, and cardiovascular risk factors of insulin, glucose, triglycerides, cholesterol, and blood pressure.[204] Primary participants are youth aged 6-11 years from an underserved community in South Phoenix, Arizona. Inclusion criteria for the *Athletes for Life* study included: (1) parent ages 18 years or older and (2) children between the ages of 6-11 years. Exclusion criteria included: (1) presence of a mental or physical condition that is contraindicated to participating in sports/exercise, (2) having a chronic condition that limits mobility, or (3) taking medications that influence body composition.

One parent was recruited to participate concurrently in the study. Community partners (i.e., recreation center and community clinic in South Phoenix) assisted with the recruitment of study participants. The recreation center sent e-mails to their extensive list of members, in addition to posting flyers in their facilities and in local public schools. The community clinic promoted the study with pediatric patients and families through lay health advisors (i.e., *promotoras*). *Promotoras* called families to remind them of their clinic visits and to promote this study. Additional recruitment efforts included recruitment and study information booths at local health fairs, farmers markets, and public-school events (e.g., Back to School Night) in the local community. A total of 1,162 potential participants were screened for eligibility.

Of these, 662 met the initial eligibility criteria based on parent self-report and 573 parent-child dyads met the study's final inclusion criteria. A total of 421 potential participants were contacted for recruitment. The *Athletes for Life* study enrolled 149 parent-child dyads; 4 dyads were dropped before randomization (e.g., no-shows) and 8 were dropped after randomization (e.g., did not complete baseline measures or any follow-up measures).

The final sample of the *Athletes for Life* study resulted in *N*=137 parent-child dyads (6 cohort groups enrolled on a rolling basis between 2014 to 2017). The full study sample consisted of 80 girls (58.4%) and 57 boys (41.6%), with ages ranging from 5 to 12 years (*M*=9.3, SD=1.7). The majority of children were born in the U.S. (93.4%) and 9 were born in Mexico (6.6%). Mean BMI percentile for children in this sample was 76.6 (*SD*=28.5); 59 children had underweight/healthy weight (43.1%) and 76 had overweight/obesity (55.5%). Parents in this sample were predominantly female (93.4%) with ages ranging from 25 to 68 years (*M*=38.3 years, SD=6.9). Over 86% of parents were born in Mexico, 10.9% were born in the U.S., and 2.9% were born in another country (i.e., Guatemala, Guyana, Iran, Syria). Most parents indicated that Spanish was their preferred language (86.1%), identified as Hispanic/Latino (95.6%), and described their child as Hispanic/Latino (95.6%). Most parents had high school or greater educational attainment (74.5%), while 25.5% had less than high school level education. Most households had monthly income of less than $3,000.

Procedures

Athletes for Life study measures were completed at the community recreation center facility and the university research facilities at baseline (pre-intervention), 12 weeks (post-intervention), and 24 weeks (follow-up). Study consents and assents were obtained for parent and child measurements. Data collected at baseline (T1) included parent and child anthropometric measurements (height and weight), parent and child accelerometer-measured

PA, and parent self-reported questionnaires. Sociodemographic and behavioral characteristics were assessed only at baseline via the self-administered parent survey, which was completed in the parent's preferred language of English or Spanish. As an incentive, enrolled families who completed baseline data collection measures were offered a Park and Recreation Department Yearly Recreation Pass. Participants who already had a pass were given a voucher to renew their membership once it expired. Children were given a toy worth approximately $5 for completing each round of data collection (0, 12, and 24 weeks) and for wearing the PA monitoring devices.[204] After baseline measures were completed, the parent-child dyads were randomized to receive the intervention immediately or assigned to a wait-list control group.

The *Athletes for Life* intervention was a family nutrition and PA program designed to improve fitness and overall family health, focused primarily on the needs of Hispanic/Latino families. The 12-week intervention targeted interpersonal (i.e., social) level factors to promote health behaviors within the built environment (i.e., community recreation center).[204] The content and structure of the *Athletes for Life* program curriculum was developed by graduate and undergraduate student research assistants at Arizona State University under the mentorship of Drs. Noe Crespo (PI) and Sonia Vega-López (Co-PI), and in close collaboration with two community partners in South Phoenix, Arizona. The program consisted of two sessions per week for 12 weeks for both parents and children, which consisted of various sports, physical activities, and nutrition education activities. Children participated in PA sessions to improve fitness and sports skills, and in short nutrition education activities to improve dietary habits. Parents participated in nutrition education and PA classes to improve their own and their children's PA and dietary behaviors. Parents were encouraged to model PA behavior for their children at home and were provided with take-home materials for self-monitoring of behaviors for both the child and the parent to reinforce concepts discussed in class. After parent-child dyads completed the 12-week program, they were invited to participate in an "Olympics" event which was designed to allow parents and children to display PA-related skills they developed throughout the program.[204] The *Athletes for Life* study was conducted between September 2014 and March 2018 following Institutional Review Board (IRB) approval from Arizona State University (ASU).

Study Measures

The current study uses child accelerometry-measured PA data, child anthropometric data, and parent survey data collected only at baseline (pre-intervention, T1).

Accelerometer-Measured Child PA

The primary outcome of this study is accelerometer-measured overall child PA. Of the 137 parent-child dyads from the full *Athletes for Life* study sample, participants from the first cohort (n=33) utilized hip-worn ActiGraph devices. However, this monitor was replaced with wrist-worn GENEActiv accelerometers which were then used throughout the study with the remainder of participants (n=104). Due to inconsistencies in activity thresholds between GENEActiv and ActiGraph devices,[205,206-209] all participants who were monitored using the ActiGraph device were excluded from the present analyses. Thus, the current study only utilizes PA data from the sub-sample of participants who used the GENEActiv accelerometer at baseline (4 cohorts, n=104 participants).

GENEActiv is a waterproof triaxial accelerometry-based activity monitor with a dynamic range of +/- 8g (i.e., gravity estimator of normal everyday activity) (Activinsights, Cambridgeshire, UK). GENEActiv data are stored directly onto the devices and expressed in units milli-g (1000 mg = 1 g = 9.81 m/s^2). GENEActiv accelerometers have been validated with adults and children[206,210-212] and have demonstrated high technical reliability and validity in determining time spent in activity intensities[210] and in distinguishing PA from sedentary behavior in children.[37-39,213] The commercial GENEActiv software (version 2.2) was used to initialize accelerometers to collect unfiltered, triaxial acceleration data at a sampling frequency of 40 Hz (i.e., collect acceleration data 40 times per second in each of the three axis).

Accelerometers were initialized the same day they were to be distributed and set to start recording data at 12AM of the following day. Children were instructed to wear the accelerometer on the same wrist (i.e., their preferred wrist) for 7 consecutive days, 24 hours per day. The *Athletes for Life* study implemented a continuous 24-hour monitoring protocol to improve compliance and minimize missing data due to non-wear, as has been previously done with free-living samples of school-aged children.[36,47,75,206,209,214-216] Children were informed that the accelerometer could be worn while showering, swimming, and/or sleeping. Children who did not wear the monitor for the requested amount of time were asked to re-wear the monitor for an additional number of days depending on how many were needed to fulfill data requirements. Following the free-living measurements, accelerometers were collected by the study's research team at ASU's research facilities. Study staff used the GENEActiv software to download data from each accelerometer monitor and PA data were saved in raw format as binary files (.bin extension).

Accelerometer Data Processing

For the current study, raw accelerometer data files were read into R and summarized using the GGIR package version 2.6-0.[217] Accelerometer data processing steps were followed as described in the GGIR package vignette (https://cran.r-project.org/web/packages/GGIR/vignettes/GGIR.html#1_Introduction). The GGIR package was developed for GENEActiv accelerometers and facilitates the analysis of the device's raw accelerometer data through several functionalities: (1) auto-calibration of triaxial accelerometer signal to local gravity to reduce calibration error; (2) detection of sustained abnormally high values; (3) detection of non-wear time; (4) calculation of acceleration metrics, i.e., the vector of magnitude of acceleration corrected for gravity (Euclidean Norm minus 1 g, ENMO) for 5-second epochs with negative values rounded up to zero (**Figure 2**); and (5) use of ENMO values with validated cut points to determine intensity of PA.[217-220]

$$\text{ENMO} = \sum \sqrt{x^2 + y^2 + z^2 - g}$$

Figure 2: Calculation of the average magnitude of dynamic acceleration (a measure indicative of overall activity).

Non-wear time was computed using detection procedures by Van Hees and colleagues.[218] Using GGIR defaults, non-wear is based on periods of sustained low acceleration, which is determined by characteristics of 15-minute blocks within a 60-minute window or by the value range of raw acceleration of each axis (x, y, z). A block is classified as non-wear time when the standard deviation of the 60-minute window is less than 13 mg and the value range of the 60-minute window is less than 50 mg for at least two of the three axes of acceleration.[218] GGIR then imputes the missing data based on average ENMO values from similar timepoints on other days and provides the *number of valid hours* to determine valid wear time and *non-wear percentage per day*.[217,218]

PA levels were classified as sedentary (<50 mg), light (50-150 mg), moderate (>150-500 mg), vigorous (>500mg), and MVPA (≥150 mg) using published intensity cut points for wrist worn GENEActiv accelerometers in children aged 7-11 years.[207,221] The cut points provided by Hildebrand et al.[207,221] were entered directly into GGIR. Sedentary time was separated from sleep using the nocturnal sleep detection algorithm in GGIR.[220] PA data were considered for preliminary analyses if post-calibration error was less than 0.02 *g* and valid data were present for every 15-minute period in a 24-hour cycle (even when data were scattered over multiple days). Participants also needed a minimum of 1 day where the GENEActiv recorded sufficient wear time.[47,216] **Table 1** shows the accelerometer data processing criteria for the current study. The R code used to process raw accelerometer data in GGIR is provided in *Appendix A*. GGIR produced output files in csv format and contained the ENMO-derived average magnitude of dynamic acceleration values expressed in average mg.[218] ENMO was averaged over 5-second epochs, as done in previous studies with children and young adolescents aged 6-12 years.[11,36,47,101,214,215,222] A shortest possible epoch length (between 1-5 seconds) is recommended to capture short bursts of MVPA due to the sporadic activity of youth.[76,218,223]

Table 1: List of Accelerometer Data Processing Criteria for the Current Study

Accelerometer data processing criterion:	**Definition in this study:**
Type of device	GENEActiv
Placement of the device	Child's preferred wrist
Filter	None (i.e., unfiltered)
Sampling frequency	40 Hz
Wear-time protocol	24-h, 7 days/week
Epoch length	5 seconds
Metric (acceleration)	ENMO (mg)
Measurement period	24 hours (midnight to midnight)
Valid days	≥ 1 day
Population age range	6-12 years (children, young adolescents)
PA intensity classification and cut points	Sedentary: <50 mg Light: 50-150 mg Moderate: >150-500 mg Vigorous: >500 mg MVPA: ≥ 150 mg

Parent Support for Child PA

For this study, parent transportation support for child's PA was studied in relation to the child's objectively measured PA.[160] Transportation support was defined as the number of times parents reported taking their child to locations for PA. The frequency of transportation to PA locations was assessed through a single item in the parent survey which was adapted from previous studies on youth PA.[160,224] Earlier and recent studies have shown that the single-item measure of parent transportation support has predictive validity for child and adolescent PA.[160,170,224] An open-ended question asked parents to write the number of times they took their child to a specific location (i.e., a park, a sporting event that they participated in, swimming, hiking, to a gym) over the past month (e.g., "In the past month, how many times did you take your child to…?"). Total transportation support was computed by adding the number of times parents took their child to each location. A higher total score for the transportation support variable (i.e., greater number of times child was transported to a location for PA) was indicative of higher transportation support for child PA.

Perceived Neighborhood Environment

Parents reported their level of agreement with statements on perceived neighborhood environment via the baseline parent survey. The *Athletes for Life* study used 16 items from the Neighborhood Environment Walkability Scale (NEWS)[225] to measure neighborhood environment characteristics hypothesized to be related to lifestyle PA. The NEWS measure is a validated scale with acceptable reliability in adult and youth populations.[180,183,225] The measure consists of 8 subscales to assess perceived environmental walkability: (1) residential density; (2) proximity to nonresidential land uses, such as restaurants and retail stores (land use mix–diversity); (3) ease of access to nonresidential uses (land use mix–access); (4) street connectivity; (5) walking/cycling facilities, such as sidewalks and pedestrian/bike trails; (6) aesthetics; (7) pedestrian traffic safety; and (8) crime safety.

The *Athletes for Life* study utilized four of these subscales to assess perceived neighborhood environment via 16 items. The *Athletes for Life* study team translated the 16

NEWS items from English-to-Spanish for use with this specific study population, following established protocols.[226] Using a 4-point response scale (1=strongly disagree, 2=somewhat disagree, 3=somewhat agree, 4=strongly agree), parents were asked to indicate their level of agreement to 16 statements within the following 4 subscales: walking/cycling facilities (3 items), aesthetics (4 items), pedestrian traffic safety (5 items), and crime safety (4 items).[183,225] These subscales have shown good internal consistency among parents of children aged 5-11 years (Cronbach's alphas: walking/cycling facilities= 0.81; aesthetics= 0.76; pedestrian traffic safety= 0.79; crime safety= 0.87).[180]

For this study, subscales scores were calculated as the mean across the subscale items, where higher scores indicate a favorable value of the environmental characteristic (e.g., less perceived crime/more safety).[180,225] Scoring was reversed for 5 items so that higher scores indicated a favorable value (**Table 2**). A total neighborhood environment score was computed by summing the scores for the 4 subscales. Internal consistency of the NEWS subscales was assessed using Cronbach's alpha.[227]

Child BMI

Child height and weight measures were conducted using a portable stadiometer and a portable electronic scale (SECA), respectively. Staff-measured height (cm) and weight (kg) were used to compute child Body Mass Index (BMI). Child BMI values (<85th percentile and ≥85th percentile BMI-for-age) were computed based on the CDC Growth Charts[228] using SAS Macro (https://www.cdc.gov/nccdphp/dnpao/growthcharts/resources/sas.htm). BMI percentile ranges were used to classify participants into the following weight status categories: 1=Underweight (< 5^{th} percentile), 2=Healthy Weight (> 5^{th} – 85^{th} percentile), 3=Overweight (> 85^{th} – 95^{th} percentile), 4=Obesity (> 95^{th} percentile).

Table 2: Neighborhood Environment Walkability Scale (NEWS) Items[180,183]

Walking/cycling facilities (3 items)
There are sidewalks on most of the streets in my neighborhood.
Sidewalks are separated from the road/traffic in my neighborhood by parked car.
There is grass/dirt strip that separates the streets from the sidewalks in my neighborhood.
Neighborhood Aesthetics (4 items)
There are trees along the streets of my neighborhood.
There are many interesting things to look at while walking in my neighborhood.
There are many attractive natural sights in my neighborhood (such as landscaping views).
There are attractive buildings/homes in my neighborhood.
Pedestrian traffic safety (5 items)
Walkers and bikers in the streets can be easily seen by people in their homes.
There are crosswalks and pedestrian signals to help walkers cross busy streets in my neighborhood.
There is so much traffic along nearby streets that it makes it difficult or unpleasant to walk in my neighborhood. *
The speed of the traffic on most nearby streets is usually slow (30 mph or less).
Most drivers exceed the posted speed limits while driving in my neighborhood. *
Crime safety (4 items)
My neighborhood streets are well lit at night.
There is a high crime rate in my neighborhood. *
The crime rate in my neighborhood makes it unsafe to go on walks during the day. *
The crime rate in my neighborhood makes it unsafe to go on walks during the night. *

**Item was reverse scored.*

Demographics Characteristics

Demographic characteristics were used to describe the sub-sample of participants from the *Athletes for Life* study who completed accelerometer measures. Data on parent, child, and household demographic characteristics were self-reported by parents at baseline (T1) using the parent survey. Child characteristics include date of birth, sex, race/ethnicity, and country of birth. Parents were asked to choose a race/ethnicity category to describe their child (response options: *Hispanic or Latino*, *Other*, *Don't Know*, *Refuse*). Child date of birth was used to compute child age in years. Parent characteristics include date of birth, sex, race/ethnicity, country of birth, and preferred language. Parent date of birth was used to compute parent age in years. Household characteristics include household monthly income and household public assistance.

Statistical Analysis

Analyses includes only data for the sub-sample of children who completed accelerometry measures in the *Athletes for Life* study. PA variables provided by the GGIR were merged with survey variables to form a single dataset for analyses. Variables of interest were screened for outliers and checked for errors by sorting data and running frequency tables. Total PA volume (mg), total PA (accumulated minutes), and daily MVPA (mean minutes) were assessed for normality through frequency distributions (histogram and normality plots). Descriptive analyses were performed for all study variables with data presented as mean ± standard deviation for continuous variables or frequencies (%) for categorical variables. All statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS), version 28.0 (SPSS, Inc. Chicago, Illinois).

Aim 1 Analyses

The first aim of this study was to characterize and compare patterns of accelerometer-measured PA of preadolescent youth (aged 6-12 years) in the *Athletes for Life* study, assess accumulation (acceleration, daily means), evaluate variations (weekday vs. weekend patterns), and examine PA differences by child characteristics (age, sex, weight status). **Table 3** describes the child activity outcome measures evaluated in this study. Accelerometer compliance was assessed by computing mean valid wear time (hours) and mean valid days. Time spent across PA intensity levels (sedentary, light, moderate, vigorous) was estimated from accelerometer data by dividing total minutes spent at each level by the total minutes in the child's waking period. Total PA was computed by combining total time (minutes) spent in light, moderate, and vigorous intensities. MVPA was assessed using an intensity threshold of 150 mg based on 5-second epochs. The MVPA intensity threshold is based on the Hildebrand et al.[207] cut points which have also been used in two recent methodological

Table 3: List of Key Child Activity Variables Assessed in this Study

Variable	Definition
Waking Time	Duration of waking time (minutes) within 24-hour day window (i.e., midnight to midnight).
Sleep Period Time	Duration of sleep period time (minutes) within 24-hour day window (i.e., midnight to midnight).
Total PA	Average daily minutes spent in light, moderate, and vigorous intensity PA during waking time.
Sedentary Time	Average daily minutes spent being sedentary (i.e., inactive) during waking time.
Light PA	Average daily minutes spent in light intensity PA during waking time.
MVPA	Average daily minutes spent in moderate and vigorous intensity PA during waking time.
MVPA Bouts	Average daily minutes of moderate and vigorous activity spent in different bout durations during waking time. *Sporadic bout duration*: < 5 minutes *Short bout duration*: 5 - < 10 minutes *Medium-to-long bout duration*: ≥ 10 minutes
PA Volume	ENMO-derived average magnitude of dynamic acceleration values expressed in average mg (during waking time and over 24-hour period).

studies with youth aged 7-15 years wearing wrist worn GENEActiv accelerometers.[36,81,214] In the Hildebrand et al.[207] study, >150 mg was found to be equivalent to ≥3 metabolic equivalent of tasks (METs), which represent MVPA. A variable for total MVPA minutes was computed by combining total minutes spent in moderate intensity and total minutes spent in vigorous intensity into a single variable. The prevalence of children meeting the current MVPA guidelines was evaluated. Participants were categorized as meeting recommended MVPA guidelines if they achieved 60 or more minutes of MVPA on *all* days of the measurement period.[58,75,81,206] Average time spent in MVPA at the three different minimum bout durations (1, 5, and 10 minutes) was also assessed.[34,92] Various bout lengths were examined to identify how the estimated accumulation of minutes of MVPA was affected by bout length criteria. Bouts of MVPA were identified as 1-, 5- or 10-minute time windows that start with a 5-second epoch value equal to or greater than 150 mg, and for which 80% of subsequent 5-second epoch values are equal to or higher than the 150 mg threshold.[217] The summary measure ENMO mg (average per day) was used as an indicator of average magnitude of dynamic wrist acceleration (i.e., PA volume) over the measurement period.[46,47]

Descriptive statistics (means, standard deviations) were used to summarize child PA outcomes (i.e., sedentary time, total PA, light PA, MVPA, MVPA bouts, PA volume). Pearson product-moment correlations were used to explore relationships among PA outcomes. Differences in accelerometer compliance by child sociodemographic characteristics were explored using independent-samples *t*-tests. Paired samples *t*-tests compared differences in PA intensity levels and between MVPA bout durations. Chi-square tests for independence explored differences by age, sex, and weight status between children who met MVPA guidelines vs. those who did not meet recommended guidelines. Independent-samples *t*-tests examined unadjusted differences in activity measures by categories of child age (5-9 years vs. 10-12 years), sex (male vs. female), and weight status (healthy weight vs. overweight/obesity). Statistical significance was set at $p < .05$ level.

A three-way between-groups multivariate analysis of variance (MANOVA) was performed to examine differences between age, sex, and weight status groups across several PA outcomes simultaneously (i.e., 2 x 2 x 2 factorial design). Eight dependent variables were used: sedentary time, total PA, light PA, MVPA, 1-5-minute MVPA bouts, 5-10-minute bouts, 10-minute MVPA bouts, and PA volume. The independent variables were age, sex, and weight status. Factorial MANOVA was selected for this analysis to control for the increased risk of Type I error involved with carrying out multiple tests on the same data. Rather than conducting separate regressions on each PA outcome variable, MANOVA allows for the inclusion of multiple dependent variables in the same analysis and considers the relationship between these variables (i.e., multivariate tests of significance). MANOVA also has the power to detect effects to indicate whether groups differ along a combination of variables (i.e., between-subject effects). The impact of the independent variables (age, sex, weight status) on each dependent variable was evaluated using effect size statistics, which represent the proportion of the variance in the dependent variable that can be explained by each independent variable. Two-way (age^{x}sex, age^{x}weight, sex^{x}weight) and three-way (age^{x}sex^{x}weight) interactions between independent variables were also examined.

Aim 2 Analyses

The second aim of this study was to assess the influence of factors within the intrapersonal (child BMI), interpersonal (parent transportation support), and environmental (parent-perceived neighborhood environment) levels on children's total PA. We use total child PA (mean mins/day) as the primary outcome for Aim 2 because it combines the full range of PA intensities (light, moderate, vigorous). Differences in transportation support by child age, sex, and weight status were examined using independent-samples *t*-tests. Spearman's rho correlations were conducted to describe the relationship between (1) transportation support and child PA, (2) transportation support and parent-perceived neighborhood environment, and (3) transportation support and child BMI. Associations between transportation support, neighborhood environment, and child PA were assessed using separate hierarchical multiple regressions, controlling for the influence of child age, sex, and BMI. Hierarchical multiple regressions were conducted to test the hypothesis that parent-perceived neighborhood environment (M_1) and child BMI percentile (M_2) moderate the relationship between transportation support and child PA (**Figure 3**).

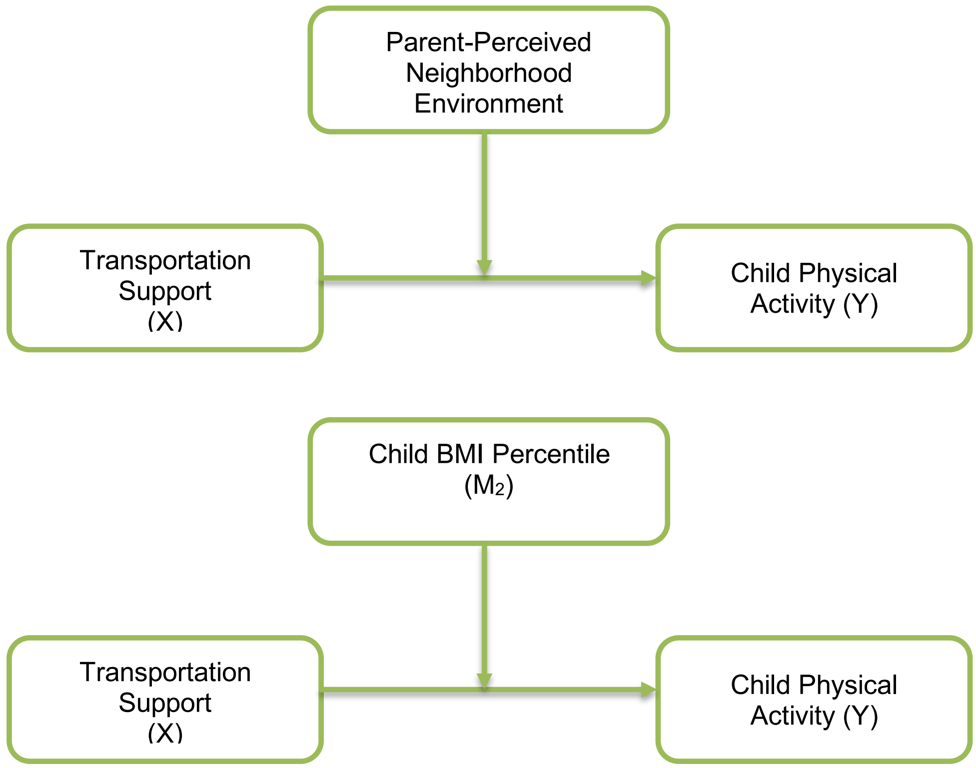

Figure 3: Conceptual moderation models to examine the influence of perceived neighborhood environment and child BMI on the relationship between transportation support and child PA.

First, two predictor variables were included (X and M) in the regression model to assess if these variables account for a significant amount of variance in total child PA (mean mins/day). Next, the interaction term between X and M was added to the regression model to assess if the interaction accounted for a significant proportion of the variance in child PA. If a potentially significant interaction was indicated, main moderation analyses were then conducted using the PROCESS macro procedure for SPSS Version 4.1.[229] Compared to normal regression tools, PROCESS helps run moderation and mediation analyses through several functions: (1) centering of predictor variables (X and M); (2) automatic computation of the interaction term (X*M); (3) conducting simple slopes analyses; and (4) generation of data for plotting effects.[229] Using PROCESS, we predicted the primary outcome (total child PA) from the predictor variable (parent support), the proposed moderators (perceived neighborhood environment, child BMI), and the interactions of predictor and moderator variables (transportation support*neighborhood environment and transportation support*child BMI). Simple slopes and zones of significance (Johnson-Neyman method) outputs were examined to assess interaction effects. Moderation was confirmed by a significant interaction effect at the $p < .05$ level.

Interaction terms were plotted using scatter/doc graphs in SPSS, and predictor variables were dichotomized for ease of interpretation. Transportation support was dichotomized as *low support* (i.e., parent took their child to a location for PA 1-3 times within the past month) vs. *high support* (i.e., parent took their child to a location for PA ≥ 4 times within the past month). Neighborhood environment was dichotomized as *favorable* (NEWS scores 1.00 to < 2.49) vs. *unfavorable* (NEWS scores 2.50 to 4.00) perceptions of neighborhood environmental attributes. Child BMI status was dichotomized as healthy weight (< 5^{th} to 85^{th} percentile) vs. overweight/obesity (> 85^{th} percentile).

Exploratory Analyses

Additional analyses explored the influence of multi-level factors on additional child activity outcomes: sedentary time (mean mins/day), light PA intensity (mean mins/day), mean MVPA (mean mins/day), 1-, 5-, 10-minute MVPA bouts (mean mins/day), and PA volume (mean mg/day). Spearman’s rho (non-parametric) correlation coefficients were used to explore associations between transportation support, perceived neighborhood environment, and activity outcomes. Moderation analyses explored the effects of parent-perceived neighborhood environment and child BMI percentile in the relationship between transportation support and additional child PA outcomes. Statistical significance for all exploratory analyses was considered at the $p < .05$ level.

RESULTS

Preliminary Analysis

Out of the 104 children asked to wear the GENEActiv devices, 27 were excluded from the PA sample (6 declined to take part in accelerometry measures and 21 used malfunctioning accelerometers which did not record PA data). This resulted in 77 raw data files containing unfiltered, time -and -date stamped triaxial acceleration data (x, y, z), in gravitational units (g), complete with negative sign indicating directionality. Next, GGIR output files were inspected, and 4 cases were excluded due to accelerometer calibration errors. These calibration errors indicated that the accelerometers did not record data and/or the child had zero hours of valid data; therefore, no PA variables were computed for these 4 cases. No extreme outliers were identified in the GGIR output files (i.e., abnormally high values were not detected by GGIR program). One case had less than 1 valid accelerometer day (i.e., 2 hours only) and was excluded from analyses. The final analytical sample involves only participants who had complete data for PA, age, sex, and BMI (n=68).

Sample Characteristics

The final analytical sample for the present study consists of 68 preadolescent youth (56% female, 44% male) between the ages of 5.9 and 12 years (mean= 9.5 years), and with at least one day of valid accelerometer data (**Table 4**). Children in this sample were predominantly Hispanic/Latino (94%) and were born in the U.S. (93%). Over half of children had overweight/obesity (54%) and an average BMI percentile of 74.7. The majority of parents in this sample were female (96%), and 87% indicated that Spanish was their preferred language. Almost 40% of households reported receiving some form of public assistance.

Table 4: Sociodemographic Characteristics of the Sub-Sample of *Athletes for Life* Study Participants Who Completed Accelerometry Measures (*N*=68)

	N (%)	**M ± SD**
Child characteristics		
Age		9.45 ± 1.73
Sex		
Female	38 (55.9)	
Male	30 (44.1)	
Hispanic/Latino (*% yes*)	64 (94.1)	
Country of Birth		
U.S.	63 (92.6)	
Mexico	5 (7.4%)	
Weight Status [a]		
Underweight (< 5^{th})	2 (2.9)	
Healthy weight (> 5^{th} – 85^{th})	29 (42.6)	
Overweight (> 85^{th} – 95^{th})	9 (13.2)	
Obesity (> 95^{th})	28 (41.2)	
BMI % [a]		74.73 ± 28.90
Parent characteristics		
Age (years)		37.44 ± 7.03
Sex		
Female	65 (95.6)	
Male	3 (4.4)	
Hispanic/Latino (*% yes*)	64 (94.1)	
Country of Birth		
U.S.	11 (16.2)	
Mexico	56 (82.4)	
Other [b]	1 (1.5)	
Language		
English	9 (13.2)	
Spanish	59 (86.8)	
Household characteristics		
Household total monthly income (n=61)		
$0 - $2999	33 (54.1)	
$3000 - $5000+	14 (23.0)	
Don't know	14 (23.0)	
Public assistance recipients [c] (*% yes*)	27 (39.7)	

[a] CDC BMI percentile for age-and-sex
[b] Other: Syria
[c] Public assistance: SNAP, EBT, Food Stamps, WIC, TANF

Aim 1 Results: Characterization and Patterns of Child PA

Accelerometer Compliance

Accelerometry data were collected between January 2016 and September 2017. Overall, our final analytic sample showed acceptable accelerometer wear compliance. About 72% of children (n=49) wore the device for the full measurement period (i.e., at least 7 days). Over 98% of children (n=67) had at least 3 days of valid accelerometer data, and over 97%

had at least 1 weekend day of accelerometer data. The average number of valid days was 6.8 days, and the average wear time was 11.3 hours per day. **Table 5** presents differences in accelerometer wear compliance by child characteristics. Older children had more valid days of accelerometer data compared to younger children (*p*= .01), and children in the overweight/obesity category had significantly less valid hours per day compared to children in the healthy weight category (*p*= .02). There were no significant sex differences in accelerometer wear compliance.

Table 5: Differences in Accelerometer Wear Compliance by Child Characteristics

		Valid Days		Valid Hours	
	n	**Mean ± SD**	***p***	**Mean ± SD**	***p***
Age					
6-9 years	33	6.42 ± 1.54	.01	11.25 ± 3.89	.47
10-12 years	35	7.20 ± 1.05		11.34 ± 3.39	
Sex					
Male	30	7.10 ± 1.47	.57	11.66 ± 3.81	.73
Female	38	6.61 ± 1.24		11.01 ± 3.48	
Weight Status					
Healthy	31	6.87 ± 1.46	.68	12.12 ± 4.25	.02
OW/OB	37	6.78 ± 1.29		10.61 ± 2.86	

Distribution of Key PA Variables

The Kolmogorov-Smirnov test was used to determine whether the distribution of scores for key PA variables were significantly different from a normal distribution. Non-significant test results (i.e., $p \geq .05$) indicated normality. Total PA, light PA, MVPA, and 1-5-minute MVPA bouts were reasonably normally distributed. The Kolmogorov-Smirnov test statistic for total PA, light PA, 1-5-minute MVPA bouts and MVPA had a *p*-value greater than .05, indicating normality. Sedentary time, 5-10-minute MVPA bouts, 10-minute MVPA bouts, and PA volume were reasonably normally distributed. Only a few cases were identified as potential outliers for sedentary time (n=3), 5-10-minute MVPA bouts (n=2), 10-

minute MVPA bouts (n=3), and PA volume (n=1). However, after closer examination, these cases were found to have values within range of possible PA scores. The means and trimmed mean values for each of these variables were also very similar (i.e., mean difference was less than 2 scale points), indicating that these potential outliers did not have a strong influence on the means. Given this, and the fact that the values were not too different from the remaining distribution, these cases were retained in the dataset.

Relationship among Key PA Variables

Pearson's correlation coefficients showed moderate, negative correlations between sedentary time and all PA variables (**Table 6**). Sedentary time was significantly associated with total PA ($p < .001$), light PA ($p < .001$), MVPA ($p < .001$), 1- to 5-minute MVPA bouts ($p < .001$), 5- to 10-minutes MVPA bouts ($p < .001$), MVPA bouts greater than 10 minutes ($p < .001$), and PA volume ($p < .001$). Pearson's correlation coefficients also showed significant positive associations between key PA variables, with exception of light PA. Light PA was associated with MVPA ($p = .02$), but not with 1- to 5-minute MVPA bouts ($p = .22$), 5- to 10-minutes MVPA bouts ($p = .55$), MVPA bouts greater than 10 minutes ($p = .32$), or PA volume ($p = .08$).

Table 6: Pearson Product-Moment Correlations between Child Activity Measures

	1	2	3	4	5	6	7	8
1. Total PA	1	-.73**	.83**	.78**	.63**	.37**	.29*	.70**
2. Sedentary time		1	-.49**	-.69**	-.61**	-.44**	-.27*	-.69**
3. Light PA			1	.29*	.15	-.07	-.12	.22
4. MVPA				1	.91**	.72**	.64**	.94**
5. $MVPA^{1\text{-}5mbt}$					1	.69**	.45**	.85**
6. $MVPA^{5\text{-}10mbt}$						1	.62**	.72**
7. $MVPA^{10mbt}$							1	.70**
8. PA volume								1

**Correlation is significant at the 0.01 level (2-tailed).
*Correlation is significant at the 0.05 level (2-tailed).

PA Accumulation and Patterns

Table 7 presents descriptive statistics of accelerometer-measured child activity over the measurement period. Within a 24-hour day window (i.e., 1440 mins/day), children spent an average of 927 minutes in waking time and an average of 513 minutes in sleep period time per day. Children spent approximately 65% of their waking time at a sedentary level, 24% in light PA intensity, 9% in moderate PA intensity, and 2% of the time in vigorous PA intensity. Paired samples *t*-tests comparing differences in PA intensity levels were all statistically significant. Children spent between 43 and 187 minutes per day in MVPA. A comparison of mean MVPA at different bout durations showed that children spent significantly more time in sporadic bouts (≥ 1 and < 5 minutes) compared to medium-to-long bouts (≥ 10 minutes) ($p < .001$) and to short bouts (≥ 5 and < 10 minutes) ($p < .001$). The average magnitude of dynamic acceleration was 73.2 mg (i.e., light PA intensity). Half of the children (n=34) in this sample met the recommended MVPA guidelines of ≥ 60 minutes of MVPA on all days. Chi-square tests for independence (with Yates Continuity Correction) indicated no significant differences in age (χ^2 (1, n=68) = .24, p= .63, *phi*= .09), sex (χ^2 (1, n=68) = .54, p= .46, *phi*= -.12), or weight status (χ^2 (1, n=68) = .95, p= .33, *phi*= -.15) between children who met current MVPA guidelines versus those who did not. Among children who did not meet the recommended guidelines, the number of days in which they did achieve at least 60 minutes of MVPA ranged between 2-6 days (*M*= 5.9 days). Only 1 child had zero days of at least 60 minutes of MVPA; 13 children achieved ≥ 60 minutes of MVPA on 1-4 days; and 20 children achieved ≥ 60 minutes of MVPA on 5-6 days.

Table 7: Descriptive Statistics of Accelerometer-Measured Child Activity

	Min.	Max.	M ± SD
Waking Time [a]			
Hours per day	13.49	17.84	15.45 ± .75
Minutes per day	809.33	1070.63	927.03 ± 45.28
Sleep Period Time [a]			
Hours per day	6.16	10.51	8.55 ± .75
Minutes per day	369.38	630.67	512.97 ± 45.28
Time Spent in Intensity Levels (mean mins/day)			
Sedentary time	427.49	749.54	597.81 ± 65.93
Light PA	157.10	315.30	226.11 ± 33.73
Moderate PA	38.20	151.60	85.87 ± 22.05
Vigorous PA	.70	46.03	17.24 ± 11.16
Total PA (mean mins/day) [b]			
Light, Moderate, and Vigorous PA	225.75	448.72	329.22 ± 51.36
MVPA (mean mins/day) [b]			
MVPA	43.04	187.05	103.12 ± 30.21
MVPA bouts lasting ≥ 1 and < 5 minutes	6.46	57.17	23.55 ± 9.90
MVPA bouts lasting ≥ 5 and < 10 minutes	0	19.52	5.20 ± 4.27
MVPA bouts lasting ≥ 10 minutes	0	51.76	8.93 ± 11.14
PA Volume (mean mg/day) [b]			
PA volume	43.59	126.35	73.17 ± 19.00
PA volume by intensity level [c]			
Sedentary	12.51	22.12	16.89 ± 1.71
Light	83.31	90.96	87.60 ± 1.54
Moderate	213.56	267.48	240.15 ± 10.93
Vigorous	640.55	1176.39	915.64 ± 121.30
Average Acceleration (mean mg/day) [d]	29.56	81.10	48.54 ± 11.53

[a] Duration of day window is 1440 minutes, which includes both waking time and sleep period time.
[b] Activity during waking hours of 24-hour day window.
[c] Sedentary: < 50 mg; Light: 50 mg -150 mg; Moderate: >150 mg – 500 mg; Vigorous: >500 mg.
[d] Average acceleration per 24-hour cycles.

Paired-samples *t*-tests were used to compare differences in key PA variables on weekdays (Monday-Friday) versus weekend days (Saturday-Sunday) (**Table 8**). Overall, children engaged in more PA on weekdays compared to weekend days in terms of total PA ($p< .001$), light PA ($p< .001$), MVPA ($p<.01$), and 1-5-minute MVPA bouts ($p< .001$). Children also had higher PA volume on weekdays compared to weekends ($p< .001$). There were no significant differences in sedentary time ($p= .07$), 5-10-minute MVPA bouts ($p= .45$), or 10-minute MVPA bouts ($p=. 39$) by days of the week.

Table 8: Comparison of Key PA Variables between Weekdays and Weekend Days*

	n	Weekdays	Weekends				
		M ± SD	**M ± SD**	***M*$_{\Delta}$**	***t***	***df***	***p***
Sedentary time	66	590.14 ± 65.07	610.43 ± 96.76	-20.29	-1.83	65	.07
Total PA	66	337.21 ± 53.53	312.63 ± 64.44	24.58	4.05	65	<.001
Light PA	66	231.33 ± 35.06	215.13 ± 42.08	16.20	4.16	65	<.001
MVPA	66	105.88 ± 30.92	95.50 ± 36.48	10.38	2.80	65	.003
MVPA$^{1\text{-}5mbt}$	66	24.77 ± 10.31	20.64 ± 12.13	4.13	3.59	65	<.001
MVPA$^{5\text{-}10mbt}$	66	5.41 ± 4.65	4.93 ± 5.67	0.48	.77	65	.45
MVPA^{10mbt}	66	9.89 ± 11.61	8.52 ± 16.03	1.37	.87	65	.39
PA volume	64	50.27 ± 12.46	44.74 ± 12.95	5.53	4.59	63	<.001

*Paired-samples *t*-tests performed only with participants with both weekday and weekend PA data.

Unadjusted Differences in PA by Child Age, Sex, and Weight Status

Independent-samples *t*-tests were used to compare sedentary time and PA measures by categories of child age (6-9 yrs. vs. 10-12 yrs.), sex (male vs. female), and weight status (healthy weight vs. overweight/obesity). On average, older children spent 48 more minutes per day at a sedentary level, compared to younger children. Younger children had significantly higher total PA (M_{Δ}= 24.9 mins/day, p= .05), MVPA (M_{Δ}= 16.6 mins/day, p= .02), 1-5-minute MVPA bouts (M_{Δ}= 3.6 mins/day , p< .01), and PA volume (M_{Δ}= 13.1 mg/day , p< .01) than older children. No significant differences were found in light PA (p= .31), 5-10-minute MVPA bouts (p= .14), or 10-minute MVPA bouts (p= .67) by child age category. There were significant sex differences in MVPA, MVPA bouts, and PA volume. Compared to boys, girls spent about 15.6 more minutes per day in MVPA (p= .03) and spent more time in 1-5-minute MVPA bouts (M_{Δ}= 4.9 mins/day, p= .04), 5-10-minute MVPA bouts (M_{Δ}= 2.6 mins/day, p= .01), and in 10-minute MVPA bouts (M_{Δ}= 7.4 mins/day, p<.01). Girls also had a higher average daily PA volume than boys (M_{Δ}= 11.3 mg/day, p= .01). There were no significant sex differences in total PA (p= .47), sedentary time (p= .91), or light PA (p= .41). Significant differences by child weight status category were found only for 10-

minute MVPA bouts and PA volume. Compared to children in the healthy weight category, children with overweight/obesity had lower PA volume (M_{Δ}= -9.2 mg/day, *p*= .05) and spent less time in 10-minute MVPA bouts (M_{Δ}= -7.1 mins/day, *p*=.01). There were no significant differences in total PA (*p*= .95), sedentary time (*p*= .80), light PA (*p*= .30), MVPA (*p*= .21), 1-5-minute MVPA bouts (*p*= .18), or 5-10-minute MVPA bouts (*p*= .14) by child weight status (Appendix **Table 23**).

Differences between Age, Sex, and Weight Status Groups Across PA Outcomes

A three-way MANOVA was performed to examine whether PA outcomes differed by child age, sex, and weight status. Preliminary assumption testing was conducted to check for normality, linearity, and equality of variance for each independent variable, with no serious violations noted. Levene's test of equality of error variances found a significant value for only one dependent variable, 10-minute MVPA bout (*p*< .001). A Bonferroni correction was applied to reduce the chance of Type I error in the analysis. A lower alpha value was set by dividing the original .05 value by the number of dependent variables in the analysis (i.e., 8).[230] Therefore, results from MANOVA's univariate analyses are considered significant at the ≤ .01 alpha value. We report partial eta squared ($P\eta^2$) statistic due to this study's small sample size and relatively unequal N values in group categories. **Table 9** presents 2 x 2 x 2 group mean comparisons for child PA outcomes. With the use of Pillai's Trace (*V*) criterion, the combined dependent variables were significantly different by levels of age and sex, but not by levels of weight status. The interactions between age and weight and for sex and weight were also significant, showing that the effect of weight status varies with levels of age and with levels of sex. There were no significant interactions between age and sex, or between age, sex, and weight status (**Table 10**).

Table 9: Group Means and Standard Deviations of Child Activity Outcomes by Levels of Child Age, Sex, and Weight

		Male		Female	
		Healthy	OW/OB	Healthy	OW/OB
ST	6-9	587.82 ± 95.03	562.80 ± 74.40	563.54 ± 75.63	577.34 ± 76.41
	10-12	614.95 ± 54.14	627.41 ± 50.54	615.10 ± 45.47	626.34 ± 25.91
Total PA	6-9	328.58 ± 46.24	342.17 ± 51.88	339.10 ± 56.82	353.75 ± 63.11
	10-12	314.98 ± 36.69	311.16 ± 41.80	330.03 ± 53.51	309.17 ± 51.00
Light PA	6-9	229.44 ± 19.84	242.06 ± 32.51	210.45 ± 25.51	237.70 ± 41.13
	10-12	229.56 ± 21.69	220.20 ± 20.53	220.69 ± 45.77	221.61 ± 41.53
MVPA	6-9	99.14 ± 30.07	100.11 ± 26.80	128.64 ± 33.81	116.04 ± 26.67
	10-12	85.42 ± 17.24	90.96 ± 25.80	109.35 ± 34.80	87.56 ± 23.13
MVPA 1-5mbts	6-9	24.25 ± 11.79	21.17 ± 7.24	35.62 ± 11.33	26.76 ± 7.87
	10-12	15.78 ± 5.98	20.60 ± 7.39	22.99 ± 10.13	19.10 ± 6.68
MVPA 5-10mbts	6-9	4.04 ± 3.08	3.66 ± 3.96	10.66 ± 5.17	5.50 ± 2.88
	10-12	2.33 ± 1.19	4.29 ± 3.49	5.66 ± 4.52	4.34 ± 4.28
MVPA 10mbts	6-9	4.82 ± 5.50	5.71 ± 9.13	13.85 ± 10.33	8.19 ± 5.02
	10-12	1.80 ± 1.26	5.60 ± 5.75	22.14 ± 17.60	2.98 ± 4.65
PA Volume	6-9	73.63 ± 15.35	71.18 ± 17.12	92.50 ± 22.41	81.22 ± 18.10
	10-12	59.00 ± 9.39	62.36 ± 12.33	79.20 ± 19.93	60.67 ± 11.13

ST= Sedentary time.

Table 10: Multivariate Tests of Factorial MANOVA

	V	$F_{7,54}$	p	$P\eta^2$
Intercept	.998	4664.184	<.001	.998
Age	.369	4.518	<.001	.369
Sex	.248	2.540	.025	.248
Weight	.156	1.431	.212	.156
Age x Sex	.141	1.269	.283	.141
Age x Weight	.272	2.888	.012	.272
Sex x Weight	.220	2.181	.050	.220
Age x Sex x Weight	.150	1.366	.239	.150

To investigate the impact of the effect of each independent variable (age, sex, weight) and their interactions on the individual dependent variables (sedentary time, total PA, light PA, MVPA, MVPA bouts, PA volume), univariate F-tests using an alpha level of ≤ .01 were performed. Pair-wise comparison of estimated marginal means adjusted for multiple analyses (not shown), followed by univariate F-tests, showed significant age differences in sedentary time, 1-5-minute MVPA bouts, and PA volume. Compared to 6-9-year-old children, 10-12-year-olds spent a considerably higher amount of time at a sedentary level (M= 620.9 vs. M=

572.9; M_Δ= 48.1 minutes, p <.01), spent less in 1-5-minute MVPA bouts (M= 19.6 vs. M= 26.9; M_Δ= -7.3 minutes, p <.01), and had lower PA volume (M= 65.4 vs. M= 79.6; M_Δ= -14.2 mg, p <.01). Age had no significant influence on total PA, light PA, MVPA, 5-10-minute MVPA bouts, or 10-minute MVPA bouts (Appendix **Table 24**).

There were significant sex differences in 5-10-minute MVPA bouts, 10-minute MVPA bouts, and PA volume. Compared to boys, girls spent a higher amount of time in 5-10-minute MVPA bouts (M= 6.5 vs. M= 3.6; M_Δ= 3.0 minutes, p <.01) and in 10-minute MVPA bouts (M= 11.8 vs. M= 4.5; M_Δ= 7.3 minutes, p <.01) and had higher PA volume (M= 78.4 vs. M= 66.8; M_Δ= 11.6 mg, p= .01). Sex had no significant influence on sedentary time, total PA, light PA, or MVPA. There were no significant differences between children with healthy weight and children with overweight/obesity in any of the individual dependent variables. There were no statistically significant interactions between *age* x *sex*, *age* x *weight*, or *age* x *sex* x *weight* on individual dependent variables. Only the *sex* x *weight* interaction reached statistical significance for 10-minute MVPA bouts (p< .01), showing that the influence of weight on 10-minute MVPA bouts is significantly different for boys and girls (Appendix **Table 24**). **Figure 4** illustrates that daily average 10-minute MVPA bouts did not differ significantly between boys with healthy weight and those with overweight/obesity. However, the daily average of 10-minute MVPA bouts among girls with healthy weight is significantly higher compared to girls with overweight/obesity.

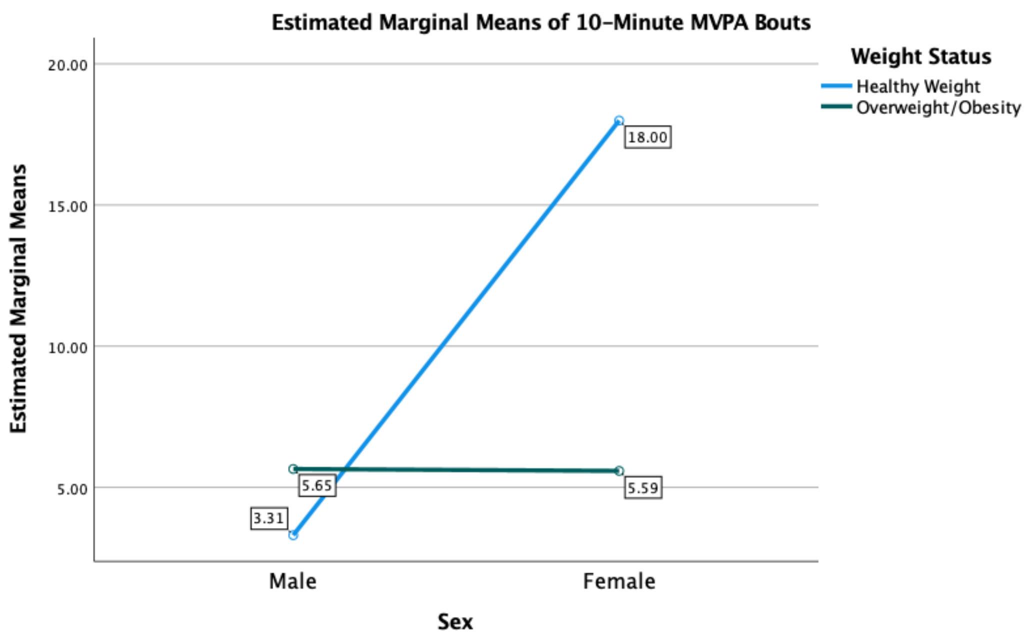

Figure 4: *Sex* x *Weight* interaction for 10-minute MVPA bouts among preadolescent youth

Aim 2 Results: Moderating Effects of Multi-Level Factors on Total Child PA

Transportation Support

The Kolmogorov-Smirnov test was used to determine whether the distribution of scores for our main predictor, transportation support, were significantly different from a normal distribution. Significant test results (i.e., $p < .001$) suggested violation of the assumption of normality for transportation support variables. Several cases were identified as potential outliers for total support (n=8), and for transportation to various locations for PA: park (n=6), sporting event (n=11), swimming (n=12), hiking (n=9), and gym (n=4). After closer examination, these cases were found to have values within range of possible transportation support scores (i.e., number of times parents reported taking their child to locations for PA within the past 30 days). The difference between the mean and trimmed mean for each variable was less than 2 scale points, indicating that the potential outliers identified did not have a strong influence on the means. Therefore, these cases were retained in the dataset.

Table 11. shows the extent of transportation support. Overall, parents reported taking children to locations for PA between 0 and 20 times over the past month. Parents reported taking their child more often to a park (66.2%) at least once during the past month, compared to locations for swimming, sporting events the child participated in, or hiking. Parents reported taking their child to the gym the least out of all locations, with 94% of parents reporting that they did not take their child to a gym on any days within the past month.

Table 11: Frequency of Parent-Reported Transportation Support within the Past 30 Days

	N (%)		**Min-Max**	**M ± SD**
	None	**≥1 time**		
No. of times parent took their child to:				
Park	23 (33.8%)	45 (66.2%)	0–20	3.71 ± 4.99
Sporting event	54 (79.4%)	14 (20.6%)	0–12	.78 ± 2.37
Swimming	45 (66.2%)	23 (33.8%)	0–20	2.46 ± 5.41
Hiking	55 (80.9%)	13 (19.1%)	0–6	.40 ± 1.05
Gym	64 (94.1%)	4 (5.9%)	0–20	.37 ± 2.45
Total transportation support	15 (22.1%)	53 (77.9%)	0–40	7.71 ± 9.92

(*N*=68)

Mean differences in transportation support by child age, sex, and weight status are shown in **Table 12**. Due to the distribution of our transportation support variables, Mann-Whitney U tests were used to compare medians (not shown) by child characteristics. Results only showed statistically significant differences by child age. Parents of children aged 10-12 years reported transporting their child more times to a gym compared to parents of younger children aged 5-9 years (p= .05). There were no significant differences by sex or weight status categories for total support or transportation to other locations for PA (i.e., park, sporting event, swimming, hiking).

Table 12: Differences in Transportation Support Frequencies[a] by Child Demographic Characteristics

	Age		Sex		Weight Status	
	5-9 yrs. (n=33)	10-12 yrs. (n=35)	Boys (n=30)	Girls (n=38)	Healthy (n=31)	OW/OB (n=37)
	M ± SD	M ± SD	M ± SD	M ± SD	M ± SD	M ± SD
Park	3.82 ± 4.86	3.61 ± 5.18	4.67 ± 6.31	2.96 ± 3.54	3.63 ± 5.63	3.78 ± 4.46
Sport	.55 ± 2.11	1.00 ± 2.61	.50 ± 2.21	1.00 ± 2.50	.84 ± 2.45	.73 ± 2.34
Swim	2.91 ± 5.97	2.03 ± 4.87	2.97 ± 5.99	2.05 ± 4.95	3.77 ± 6.89	1.35 ± 3.47
Hike	.33 ± 1.11	.46 ± 1.01	.50 ± 1.33	.32 ± .78	.48 ± .89	.32 ± 1.18
Gym	.00 ± .00	.71 ± 3.40	.03 ± .18	.63 ± 3.27	.68 ± 3.59	.11 ± .52
Total	7.61 ± 9.51	7.81 ± 10.42	8.67 ± 11.66	6.96 ± 8.39	9.40 ± 12.46	6.30 ± 7.02

[a] Average number of times within the last 30 days that parents took their child to a location for PA.

Neighborhood Environment

Parent-perceived neighborhood environment, our proposed moderator, was measured via the NEWS scale. The Kolmogorov-Smirnov test was used to determine whether the distribution of scores were significantly different from a normal distribution. Non-significant test results (i.e., $p \geq .05$) indicated normality of total neighborhood environment scores and NEWS subscale scores, and no potential outliers were identified. The NEWS scale showed good internal consistency overall ($\alpha = .81$), and for three of its subscales: walking/cycling facilities, aesthetics, and crime safety. Cronbach alphas for these three subscales are similar to those from a study with parents of children ages 5-11 and adolescents ages 12-18.[180] Only the 5-item pedestrian traffic safety subscale did not show good internal consistency. **Table 13** shows the mean scores for the NEWS total scale and its subscales. Lower mean scores (1.00–2.49) represent perceptions of unfavorable neighborhood environmental attributes, whereas higher mean scores (2.50–4.00) represent perceptions of favorable neighborhood attributes (i.e., more PA-supportive neighborhood characteristics). The mean score for the total NEWS scale was just over the midpoint ($M = 2.7$). A closer examination of NEWS subscales showed higher mean scores for walking/cycling facilities, crime safety, and pedestrian traffic safety. Mean scores for the neighborhood aesthetics subscale and its individual items were lower.

Table 13: Parent Scores on the Neighborhood Environment Walkability Scale (NEWS)

	N	M ± SD	Min – Max
Walking/cycling facilities [a] (α = .76) (Rosenberg, α = .81)	68	2.95 ± 1.08	1 – 4
There are sidewalks on most of the streets in my neighborhood.		3.37 ± 1.18	
Sidewalks are separated from the road/traffic in my neighborhood by parked car.		2.96 ± 1.29	
There is a grass/dirt strip that separates the streets from the sidewalks in my neighborhood.		2.51 ± 1.45	
Neighborhood aesthetics [b] (α = .81) (Rosenberg, α = .76)	68	2.44 ± 1.00	1 – 4
There are trees along the streets in my neighborhood.		2.96 ± 1.23	
There are many interesting things to look at while walking in my neighborhood.		2.34 ± 1.28	
There are many attractive natural sights in my neighborhood (such as landscaping views).		2.26 ± 1.25	
There are attractive buildings/homes in my neighborhood.		2.21 ± 1.29	
Pedestrian traffic safety [c] (α = .48) (Rosenberg, α = 0.79)	68	2.63 ± .75	1 – 4
Walks and bikers in the streets can be easily seen by people in their homes.		2.53 ± 1.37	
There are crosswalks and pedestrian signals to help walkers cross busy streets in my neighborhood.		2.71 ± 1.36	
There is so much traffic along nearby streets that it makes it difficult or unpleasant to walk in my neighborhood. [Reversed score]		2.90 ± 1.30	
The speed of the traffic on most nearby streets is usually slow (30 mph or less).		2.96 ± 1.28	
Most drivers exceed the posted speed limits while driving in my neighborhood. [Reversed score]		2.06 ± 1.28	
Crime safety [d] (α = .76) (Rosenberg, α = 0.87)	68	2.85 ± .94	1 – 4
My neighborhood streets are well lit at night.		2.47 ± 1.29	
There is a high crime rate in my neighborhood. [Reversed score]		2.84 ± 1.23	
The crime rate in my neighborhood makes it unsafe to go on walks during the day. [Reversed score]		3.40 ± 1.01	
The crime rate in my neighborhood makes it unsafe to go on walks during the night. [Reversed score]		2.71 ± 1.35	
Total Neighborhood Environment (α = .81) (Rosenberg, α = 0.81)	68	2.70 ± .65	1.38 – 4.00

Response options: 1=strongly disagree, 2=somewhat disagree, 3=somewhat agree, 4=strongly agree. [a]Higher scores indicate better pedestrian infrastructure. [b]Higher scores indicate better neighborhood aesthetics. [c]Higher scores indicate better perceived safety. [d]Higher scores indicate lower perceptions of crime/more safety.

Relationships between Child PA, Transportation Support, Neighborhood Environment, and BMI

Spearman's rho correlation coefficients were used to explore relationships between child PA, transportation support (total and by different location), parent-perceived neighborhood environment (total and by subscales), and child BMI (**Table 14**). There were no significant correlations between child PA and total transportation support (p= .70) or between child PA and any of the different locations for PA. However, child PA had a strong, positive correlation with parent-perceived neighborhood environment in terms of the total score ($p = .01$) and for the neighborhood aesthetics ($p = .01$) and pedestrian traffic safety ($p = .02$) subscales, with higher levels of perceived neighborhood environmental attributes associated with higher levels of child PA. There was no significant correlation between child PA and BMI ($p = .87$). In terms of transportation support, there was a significant positive correlation between the number of times parents reported taking their children to a park and to a sporting event the child participated in ($p < .01$), and the number of times they reported taking to the gym ($p = .02$). There was no significant relationship between total transportation support and total perceived environment ($p = .30$), but there was a significant positive correlation between greater perceptions of neighborhood aesthetics and the number of times parents took their child to the park ($p = .02$) and greater perceptions of pedestrian traffic safety and the number of times parents took their child hiking ($p < .01$). Among neighborhood environment subscales, positive significant correlations were found between walking/cycling facilities and aesthetics ($p = .02$); walking/cycling facilities and crime safety ($p = .03$); pedestrian traffic safety and walking/cycling facilities ($p = .01$); pedestrian traffic safety and aesthetics ($p = .004$); pedestrian traffic safety and crime safety ($p = .01$); and between crime safety and aesthetics ($p = .002$). Results showed no significant correlation between total transportation support and child BMI percentile ($p = .87$) or between total neighborhood environment and child BMI ($p = .26$).

Table 14: Spearman's Rho Correlations between the Primary Outcome (Child PA), Main Predictor (Transportation Support), and Proposed Moderators (Parent-Perceived Neighborhood Environment and Child BMI)

	1	2	3	4	5	6	7	8	9	10	11	12	13
1.Child PA	1	-.05	.12	-.11	-.17	.01	-.07	.31*	.02	.31**	.29*	.23	-.02
2.Support		1	.80**	.46**	.55**	.39**	.34**	.06	.04	.12	.13	-.06	-.03
3.Support: Park			1	.35**	.18	.22	.28*	.13	.04	.28*	.12	.000	.09
4.Support: Sport				1	.21	.20	.01	-.09	-.07	-.004	.02	-.18	-.09
5.Support: Swim					1	.15	.21	-.09	-.02	-.13	-.04	-.004	-.13
6.Support: Hike						1	.19	.21	.12	.12	.35**	.04	-.09
7.Support: Gym							1	-.09	-.24	.06	-.01	-.05	.04
8.Environment								1	.64**	.74**	.71**	.71**	.14
9.Environment: WCF									1	.29*	.34**	.32**	.03
10.Environment: AE										1	.35**	.37**	.17
11.Environment: PTS											1	.34**	.07
12.Environment: CS												1	.06
13.Child BMI													1

**Correlation is significant at the 0.01 level (2-tailed).
*Correlation is significant at the 0.05 level (2-tailed).
WCF: Walking/cycling facilities; AE: Aesthetics; PTS: Pedestrian traffic safety; CS: Crime safety.

Adjusted Associations between Support and Environment on Child PA

Hierarchical multiple regression was used to assess if transportation support predicted levels of total child PA, after controlling for the influence of child age, sex, and BMI (**Table 15**). Transportation support was entered in Block 1 (unadjusted model); transportation support, age, and sex were entered in Block 2 (adjusted model); transportation support, age, sex, and BMI percentile were entered in Block 3 (adjusted model). Transportation support was not significantly associated with child PA in the overall sample. Transportation support explained only 0.2% of the variance in child PA (Block 1). After entry of child age and sex in Block 2, the total variance in child PA explained in the model was 6.9%, $F(3, 64)= 1.59$, $p= .20$, and child age and sex explained only an additional 6.8% of the variance in child PA. After entry of child BMI in Block 3, the total variance in child PA explained in the model as a whole was 8.6%, $F(4, 63)= 1.48$, $p= .22$, and BMI explained only an additional 1.7% of the variance in child PA. In the final model, only child age predicted total child PA ($p= .03$).

Table 15: Adjusted Associations between Total Transportation Support and Total Child PA

	Unstandardized Coefficients		Standardized Coefficients		95% CI	
	b	SE B	β	*p*	Lower	Upper
Block 1						
Constant	330.94	7.96		<.001	315.04	346.85
Support	-.22	.64	-.04	.73	-1.50	1.05
Block 2						
Constant	394.62	35.48		<.001	323.74	465.51
Support	-.19	.63	-.04	.76	-1.45	1.06
Child age	-7.30	3.58	-.25	.05	-14.45	-.14
Child sex	9.08	12.43	.09	.47	-15.75	33.90
Block 3						
Constant	383.28	35.00				
Support	-.07	.64	-.01	.91	-1.34	1.20
Child age	-8.25	3.69	-.28	.03	-15.62	-.88
Child sex	11.46	12.61	.11	.37	-13.74	36.66
Child BMI	.24	.23	.14	.29	-.21	.70

Block 1: R^2 = .002 (p= .73); Block 2: ΔR^2 = .068 (p= .11); Block 3: ΔR^2 = .017 (p= .29).

Additional multiple regressions were performed to explore if types of transportation support (i.e., transportation to different locations for PA) predicted levels of child PA, controlling for child age, sex, and BMI. Findings showed no significant associations between the types of transportation support and child PA (not shown).

A separate hierarchical multiple regression was performed to assess if parent-perceived neighborhood environment predicted levels of child PA, after controlling for the influence of child age, sex, and BMI (**Table 16**). Neighborhood environment was entered in Block 1 (unadjusted model); neighborhood environment, age, and sex were entered in Block 2 (adjusted model); neighborhood environment, age, sex, and BMI percentile were entered in Block 3 (adjusted model). Neighborhood environment was significantly associated with child PA in the overall sample, explaining 9.9% of the variance in PA. After entry of child age and

Table 16: Adjusted Associations between Parent-Perceived Neighborhood Environment and Total Child PA

	Unstandardized Coefficients		Standardized Coefficients		95% CI	
	b	SE B	β	*p*	Lower	Upper
Block 1						
Constant	262.32	25.54		<.001	211.32	313.31
Environment	24.80	9.21	.32	.01	6.42	43.18
Block 2						
Constant	326.68	41.74		<.001	243.30	410.07
Environment	23.82	9.06	.30	.01	5.73	41.91
Child age	-6.98	3.41	-.24	.05	-13.78	-.17
Child sex	7.54	11.79	.07	.53	-16.01	31.10
Block 3						
Constant	323.39	42.16		<.001	239.14	407.64
Environment	22.67	9.23	.29	.02	4.22	41.12
Child age	-7.60	3.53	-.26	.04	-14.66	-.54
Child sex	9.01	12.02	.09	.46	-15.00	33.02
Child BMI	.15	.22	.09	.48	-.28	.59

Block 1: R^2 = .099 (p= .01); Block 2: ΔR^2 = .060 (p=.11); Block 3: ΔR^2 = .007 (p=.48).

sex in Block 2, the total variance in child PA explained in the model was 15.9%, $F(3, 64)= 4.03$, $p= .01$, and child age and sex explained an additional 6% of the variance in child PA. After entry of child BMI in Block 3, the total variance in child PA explained in the model as a whole was 16.6%, $F(4, 63)= 3.13$, $p= .02$, and BMI explained only an additional 0.7% of the variance in child PA. These results show that, after controlling for child age, sex, and BMI, higher neighborhood environment scores predicted higher levels of child PA ($p= .02$). Additional multiple regressions were performed to explore if neighborhood environment subscale scores predicted levels of child PA, after controlling for age, sex, and BMI. Higher scores for perceived neighborhood aesthetics (i.e., more appealing neighborhood characteristics), pedestrian traffic safety (i.e., neighborhood streets safe from traffic), and crime safety (i.e., lower neighborhood crime) were associated with higher child PA. Neighborhood aesthetics, child age, sex, and BMI explained 15.6% of the variance in child PA ($F(4, 63)= 2.92$, $p= .03$). Pedestrian traffic safety, child age, sex, and BMI explained 18.6% of the variance in child PA ($F(4, 63)= 3.61$, $p= .01$). Crime safety, child age, sex, and BMI explained 37.7% of the variance in child PA ($F(4, 63)= 2.61$, $p= .04$) (not shown).

Moderating Impact of Neighborhood Environment

Hierarchical multiple regression was used to assess the impact of parent-perceived neighborhood environment as a moderating variable in the relationship between parent transportation support and child PA. To test moderation, we looked at the interaction between total transportation support (X) and total neighborhood environment (M_1) and whether or not such an effect was significant in predicting child PA (Y). Prior to analyses, the transportation support and neighborhood environment variables were mean centered. First, a regression model was fitted predicting child PA from both total transportation support and total neighborhood environment (Block 1). Transportation support and neighborhood environment accounted for a significant amount of variance in child PA, $R= .32$, $F(2, 65)= 3.67$, $p=.03$. Next, the interaction term between transportation support and perceived neighborhood environment was added to the regression model (Block 2), which did not account for significantly more variance in child PA, $\Delta R^2= .08$, $p=.21$. Then, child age and sex were added to the model in Block 3 but did not account for significantly more variance in child PA, $\Delta R^2 = .11$ ($p= .13$) (**Table 17**). Main moderation analyses using the PROCESS procedure in SPSS showed a non-significant interaction effect, $b= .97$, 95% CI [-.02, 1.96], $t= 1.95$, $p= .24$ confirming that parent-perceived neighborhood environment did not moderate the relationship between total transportation support and child PA.

Table 17: Hierarchical Multiple Regression Assessing Parent-Perceived Neighborhood Environment as a Moderator in the Relationship between Transportation Support and Total Child PA (Mean Mins/Day)

	Unstandardized Coefficients		Standardized Coefficients		95% CI	
Model	***b***	**SE B**	**β**	***p***	**Lower**	**Upper**
Block 1						
Constant	264.08	26.06		<.001	212.04	316.12
Support	-.25	.61	-.05	.68	-1.47	.97
Environment	24.86	9.27	.32	.01	6.36	43.37
Block 2						
Constant	287.92	31.98		<.001	224.02	351.81
Support	-3.16	2.37	-.61	.19	-7.89	1.56
Environment	16.16	11.48	.21	.16	-6.77	39.09
Support x Environment	1.06	.83	.59	.21	-.60	2.72
Block 3						
Constant	347.58	45.14		<.001	257.34	437.81
Support	-2.89	2.33	-.56	.22	-7.55	1.77
Environment	15.94	11.31	.20	.16	-6.67	38.54
Support x Environment	.97	.82	.54	.24	-.67	2.60
Child age	-6.72	3.43	-.23	.06	-13.60	.13
Child sex	7.57	11.88	.07	.57	-16.19	31.33

Block 1: R = .318, $F(2, 65)$= 3.667, p= .031.
Block 2: R^2 = .124, $F(3, 64)$= 3.009, p= .037; ΔR^2 = .022, p= .207.
Block 3: R^2 = .179, $F(5, 62)$= 2.712, p= .028; ΔR^2 = .056, p= .130.

Separate regressions were performed to assess the impact of parent-perceived neighborhood environment as a moderating variable in the relationship between different types of transportation support (i.e., transportation to park, sporting event, swimming, hiking, gym) and child PA (not shown). Main moderation analyses confirmed non-significant interaction terms between total neighborhood environment and different types of transportation support on child PA: transportation to park (b= 1.17, 95% CI [-.45, 2.80], t= 1.45, p= .15); transportation to a sporting event their child participated in (b= 12.47, 95% CI [-2.23, 27.17], t= 1.70, p= .09); transportation to a location for swimming (b= 1.23, 95% CI [-1.30, 3.77], t= .97, p= .33); transportation to a location for hiking (b= .53, 95% CI [-19.50, 20.56], t= .05, p= .96); transportation to the gym (b= 2.98, 95% CI [-4.67, 10.63], t= .78, p= .44).

Moderating Impact of Child BMI

Hierarchical multiple regression was used to assess the impact of child BMI percentile as a moderating variable in the relationship between parent transportation support and child PA. To test moderation, we looked at the interaction effect between total transportation support (X) and child BMI for-age-and-sex percentile (M_2) and whether or not such an effect was significant in predicting child PA (Y). A regression model was fitted predicting child PA from both transportation support and child BMI (Block 1), which showed that transportation support and child BMI did not account for a significant amount of variance in overall child PA, R^2= .004, F(2, 65)= .14, p=.87 (**Table 18**). Next, the interaction term between transportation support and child BMI was added to the regression model (Block 2), which did not account for significantly more variance in child PA (p= .97). Main moderation analyses showed a non-significant interaction term, b= -.001, 95% CI [-.05, .05], t= -.03, p= .97, confirming that child BMI percentile did not moderate the relationship between transportation support and total child PA.

Table 18: Hierarchical Multiple Regression Assessing Child BMI Percentile [a] as a Moderating Variable in the Relationship between Transportation Support and Total Child PA (Mean Mins/Day)

	Unstandardized Coefficients		**Standardized Coefficients**		**95% CI**	
Model	***b***	**SE B**	**β**	***p***	**Lower**	**Upper**
Block 1						
Constant	323.89	19.19		<.001	285.56	362.22
Support	-.18	.65	-.04	.78	-1.48	1.11
Child BMI	.09	.22	.05	.69	-.36	.54
Block 2						
Constant	323.36	23.80		<.001	275.81	370.91
Support	-.13	1.56	-.03	.94	-3.25	2.99
Child BMI	.10	.30	.06	.75	-.50	.70
Support x Child BMI	-.001	.02	-.01	.97	-.05	.04

[a] CDC BMI percentile for age-and-sex.
Block 1: R^2 = .004, F(2, 65)= .143, p= .867.
Block 2: ΔR^2 = .000 (p= .970).

Separate regressions were performed to assess the impact of child BMI percentile as a moderating variable in the relationship between different types of transportation support (i.e., transportation to park, sporting event, swimming, hiking, gym) and child PA. Main moderation showed that the relationship between transportation support to a gym and child PA was moderated by child BMI (b= .97, 95% CI [.39, 1.55], t= 3.34, p< .01), suggesting that greater frequency of transportation to a gym is associated with higher PA among children with overweight/obesity (**Figure 11** in Appendix). However, given that 94% of parents report taking their child to the gym on zero days within the past month, this result is likely methodological (i.e., Type II error). The interaction terms between BMI and other types of transportation support on child PA were non-significant: transportation to park (b= -.04, 95% CI [-.10, .02], t= -1.24, p= .22); sporting event their child participated in (b= -.01, 95% CI [-.09, .07], t= -.29, p= .77); location for swimming (b= .01, 95% CI [-.08, .10], t= .15, p= .88); location for hiking (b= -.04, 95% CI [-.85, .77], t= -.09, p= .93).

Exploratory Aim Results: Multi-Level Factors and Additional PA Outcomes

Associations between Transportation Support and Child Activity Outcomes

Spearman's rho correlation coefficients were used to explore the relationship between transportation support (total and by different locations for PA) and additional child activity outcomes: sedentary time (mean mins/day), light PA (mean mins/day), MVPA (mean mins/day), 1-5-minutes MVPA bouts (mean mins/day), 5-10-minute MVPA bouts (mean mins/day), 10-minute MVPA bouts (mean mins/day), and PA volume (mean mg/day) (**Table 19**). There was a significant negative correlation between the number of time parents took their child swimming and total MVPA (p= .03) and the number of time parents took their child swimming and 5-10-minute MVPA bouts (p= .02). There were no significant

Table 19: Spearman's Rho Correlations between Transportation Support (Total and by Location) and Additional Child Activity Outcomes

	Total	***Park***	***Sporting event***	***Swimming***	***Hiking***	***Gym***
ST	-.10	-.22	.13	.07	-.05	.04
LPA	.01	.15	-.03	-.01	.02	-.11
MVPA	-.14	.02	-.14	-.25*	-.02	-.02
$MVPA^{1\text{-}5mbts}$	-.06	.06	-.11	-.21	-.11	-.07
$MVPA^{5\text{-}10mbts}$	-.01	.11	.14	-.28*	-.002	-.05
$MVPA^{10mbts}$	-.08	-.02	-.06	-.23	.08	.02
PA Volume	-.04	.07	-.08	-.21	-.03	-.01

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

correlations between total transportation support and additional child activity outcomes: sedentary time (*p*= .42), light PA (*p*= .96), MVPA (*p*= .27), 1-5-minute MVPA bouts (*p*= .61), 5-10-minute MVPA bouts (*p*= .92), 10-minute MVPA bouts (*p*= .50), PA volume (*p*= .73).

Associations between Neighborhood Environment and Child Activity Outcomes

Pearson product-moment correlation coefficients were used to explore the relationship between parent-perceived neighborhood environment (perceived neighborhood environmental attributes) and additional child activity outcomes: sedentary time (mean mins/day), light PA (mean mins/day), MVPA (mean mins/day), 1-5-minutes MVPA bouts (mean mins/day), 5-10-minute MVPA bouts (mean mins/day), 10-minute MVPA bouts (mean mins/day), and PA volume (mean mg/day) (**Table 20**). Higher sedentary time was significantly correlated to lower total neighborhood environment scores (*p*= .002), and with lower scores for perceived neighborhood aesthetics (*p*= .002) and pedestrian traffic safety (*p*= .004) subscales. Light PA had a significant positive correlation with higher neighborhood

Table 20: Pearson-Product Moment Correlations Between Parent-Perceived Neighborhood Environment (Total and by Subscale) and Additional Child Activity Outcomes

	Total	*Walking/cycling facilities*	*Neighborhood aesthetics*	*Pedestrian traffic safety*	*Crime safety*
ST	-.38**	-.12	-.36**	-.35**	-.20
LPA	.24*	-.05	.22	.26*	.22
MVPA	.27*	-.001	.28*	.29*	.16
MVPA$^{1\text{-}5mbts}$	.24	.05	.22	.22	.16
MVPA$^{5\text{-}10mbts}$	.13	.07	.16	.13	-.004
MVPA ^{10mbts}	.08	-.04	.10	.17	-.01
PA Volume	.16	-.07	.22	.23	.06

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

walkability (*p*= .05) and higher scores for perceived pedestrian traffic safety (*p*= .04). MVPA had a significant positive correlation with higher neighborhood walkability (*p*= .03), and with higher scores for perceived neighborhood aesthetics (*p*= .02) and pedestrian traffic safety (*p*= .02).

Associations between BMI Percentile and Child Activity Outcomes

Pearson product-moment correlation coefficients were used to explore the relationship between child BMI-for-age-and-sex percentile and additional child activity outcomes: sedentary time (mean mins/day), light PA (mean mins/day), MVPA (mean mins/day), 1-5-minutes MVPA bouts (mean mins/day), 5-10-minute MVPA bouts (mean mins/day), 10-minute MVPA bouts (mean mins/day), and PA volume (mean mg/day) (not shown). Higher BMI percentile was significantly correlated with lower 10-minute MVPA bouts (*p*= .03) and with lower PA volume (*p*= .03). Child BMI was not significantly correlated with sedentary time (*p*= .77), light PA (*p*= .08), 1-5-minute MVPA bouts (*p*= .06), or with 5-10-minute MVPA bouts (*p*= .18).

Moderating Impact of Neighborhood Environment on additional Child Activity Outcomes

Hierarchical multiple regressions were performed to explore the impact of parent-perceived neighborhood environment as a moderating variable in the relationship between parent transportation support and child PA. To test moderation, we looked at the interaction between total transportation support and total neighborhood environment and whether or not such an effect was significant in predicting child activity: sedentary time (mean mins/day), light PA (mean mins/day), MVPA (mean mins/day), 1-5-minutes MVPA bouts (mean mins/day), 5-10-minute MVPA bouts (mean mins/day), 10-minute MVPA bouts (mean mins/day), and PA volume (mean mg/day). The interaction between transportation support and neighborhood environment on sedentary time had a similar magnitude of effect as MVPA; however, the interaction on sedentary time was not significant. The results from the main moderation analyses performed using the PROCESS procedure in SPSS are shown in **Table 21**.

Parent-perceived neighborhood environment moderated the relationship between transportation support and MVPA ($p < .001$), 1-5-minute MVPA bouts ($p < .001$), 10-minute MVPA bouts ($p = .03$), and PA volume ($p < .01$). Higher transportation support for child PA was associated with higher MVPA (**Figure 5**), 1-5-minute MVPA bouts (**Figure 6**), 10-minute MVPA bouts (**Figure 7**), and PA volume (**Figure 8**) when parents perceived a more favorable neighborhood environment. Conversely, when parents perceived a less favorable neighborhood environment, the direction in the relationship between transportation support and child PA changed (i.e., negative association).

Table 21: Main Moderation Analyses Exploring Parent-Perceived Neighborhood Environment as a Moderator in the Relationship between Total Transportation Support and Additional Child Activity Outcomes, Adjusted for Age and Sex

Model	β	SE	*t*	*p*	95% CI	
					Lower	**Upper**
Sedentary Time [a]						
Constant	472.37	45.27	10.43	<.001	381.87	562.87
Support	-.40	.59	-.67	.51	-1.58	.79
Environment	-36.00	10.31	-3.49	<.01	-56.61	-15.40
Support x Environment	-1.25	.73	-1.73	.09	-2.70	.20
Child age	13.34	4.20	3.18	<.01	4.95	21.73
Child sex	-.94	14.18	-.07	.95	-29.29	27.40
Light PA [b]						
Constant	246.22	23.43	10.51	<.001	199.38	293.06
Support	-.11	.33	-.33	.74	-.76	.54
Environment	12.66	6.85	1.85	.07	-1.02	26.35
Support x Environment	-.12	.40	-.30	.76	-.92	.67
Child age	-1.67	2.39	-.70	.49	-6.46	3.11
Child sex	-7.67	7.47	-1.03	.31	-22.60	7.25
MVPA [c]						
Constant	142.17	16.50	8.62	<.001	109.18	175.16
Support	-.17	.27	-.64	.53	-.72	.37
Environment	10.73	4.44	2.42	.02	1.85	19.61
Support x Environment	1.09	.28	3.92	**<.001**	.53	1.64
Child age	-5.04	1.62	-3.12	<.01	-8.28	-1.81
Child sex	15.24	6.06	2.52	.01	3.14	27.35
$MVPA^{1\text{-}5mbts}$ [d]						
Constant	39.48	5.02	7.86	<.001	29.44	49.52
Support	-.01	.08	-.10	.92	-.16	.15
Environment	3.00	1.41	2.13	.04	.19	5.82
Support x Environment	.34	.09	3.85	**<.001**	.16	.51
Child age	-1.98	.50	-3.99	<.001	-2.97	-.99
Child sex	4.92	1.94	2.54	.01	1.05	8.79
$MVPA^{5\text{-}10mbts}$ [e]						
Constant	7.14	2.17	3.29	<.001	2.81	11.47
Support	-.02	.05	-.44	.66	-.12	.07
Environment	.64	.82	.78	.44	-1.00	2.28
Support x Environment	.08	.08	1.06	.29	-.07	.24
Child age	-.36	.21	-1.69	.10	-.78	.07
Child sex	2.59	.94	2.77	.01	.72	4.46
$MVPA^{10mbts}$ [f]						
Constant	.19	5.49	.03	.97	-10.78	11.15
Support	-.06	.13	-.44	.66	-.32	.21
Environment	.82	2.15	.38	.70	-3.48	5.12
Support x Environment	.53	.24	2.17	**.03**	.04	1.02
Child age	.48	.54	.88	.38	-.61	1.56
Child sex	7.46	2.29	3.25	<.01	2.87	12.04

Table 21: Main Moderation Analyses Exploring Parent-Perceived…, Continued

Model	β	SE	*t*	*p*	95% CI Lower	95% CI Upper
PA Volume [g]						
Constant	103.66	10.59	9.79	<.001	82.50	124.83
Support	-.05	.16	-.29	.77	-.37	.28
Environment	3.51	3.10	1.13	.26	-2.69	9.70
Support x Environment	.66	.22	3.02	**<.01**	.22	1.09
Child age	-3.91	1.04	-3.74	<.001	-6.00	-1.82
Child sex	11.42	3.74	3.05	<.01	3.93	18.90

[a] R= .54, R^2= .29, F(5, 62)= 7.84, p< .001. [b] R= .28, R^2= .08, F(5, 62)= 1.30, p= .28. [c] R= .54, R^2= .29, F(5, 62)= 10.35, p< .001. [d] R= .55, R^2= .30, F(5, 62)= 10.82, p< .001. [e] R= .39, R^2= .15, F(5, 62)= 3.60, p= .01. [f] R= .48, R^2= .23, F(5, 62)= 3.48, p= .01. [g] R= .56, R^2= .31, F(5, 62)= 9.39, p< .001.

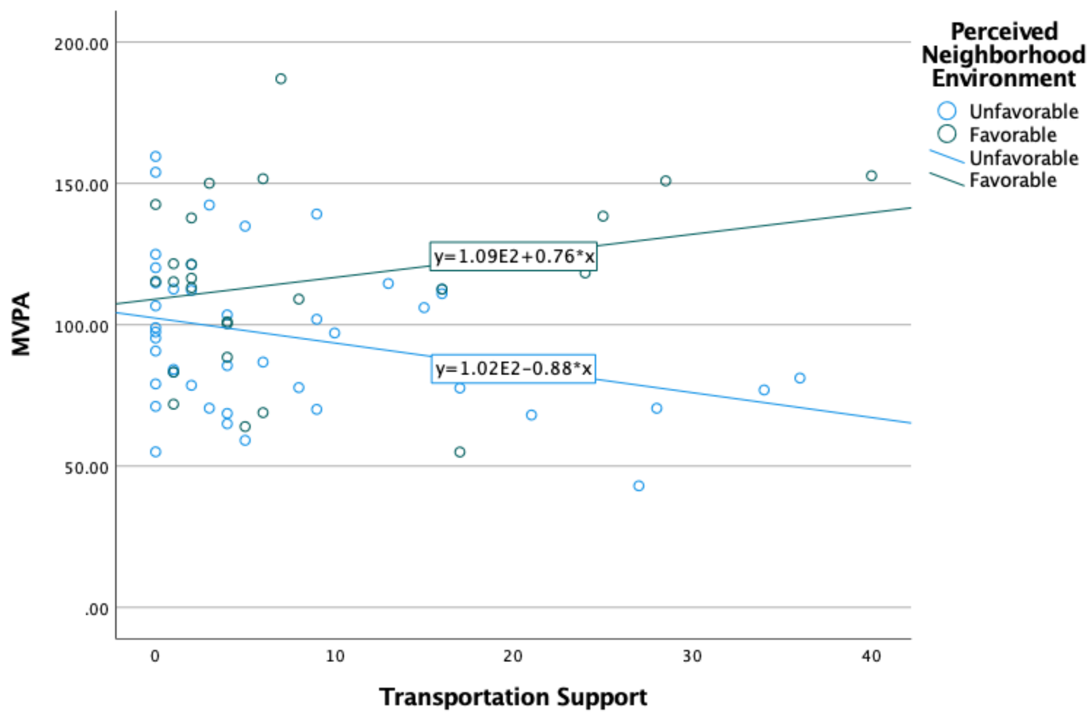

Figure 5: Main moderation analyses examining parent-perceived neighborhood environment as a moderating variable in the relationship between total transportation support and child MVPA (mean mins/day).

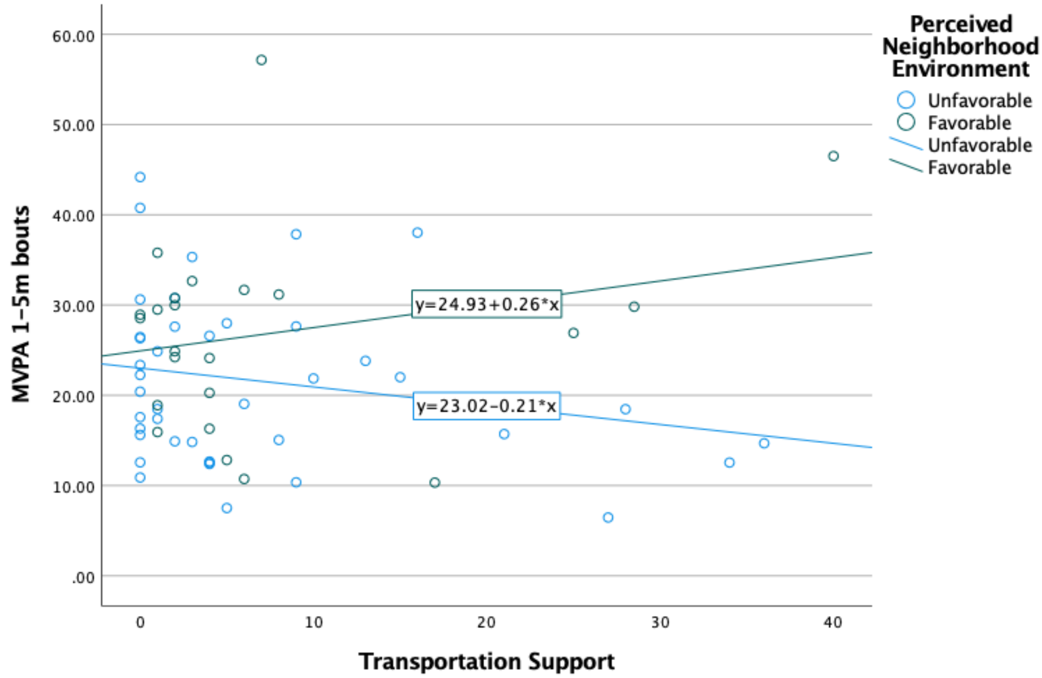

Figure 6: Main moderation analyses examining parent-perceived neighborhood environment as a moderating variable in the relationship between total transportation support and child 1-5-minute MVPA bouts (mean mins/day).

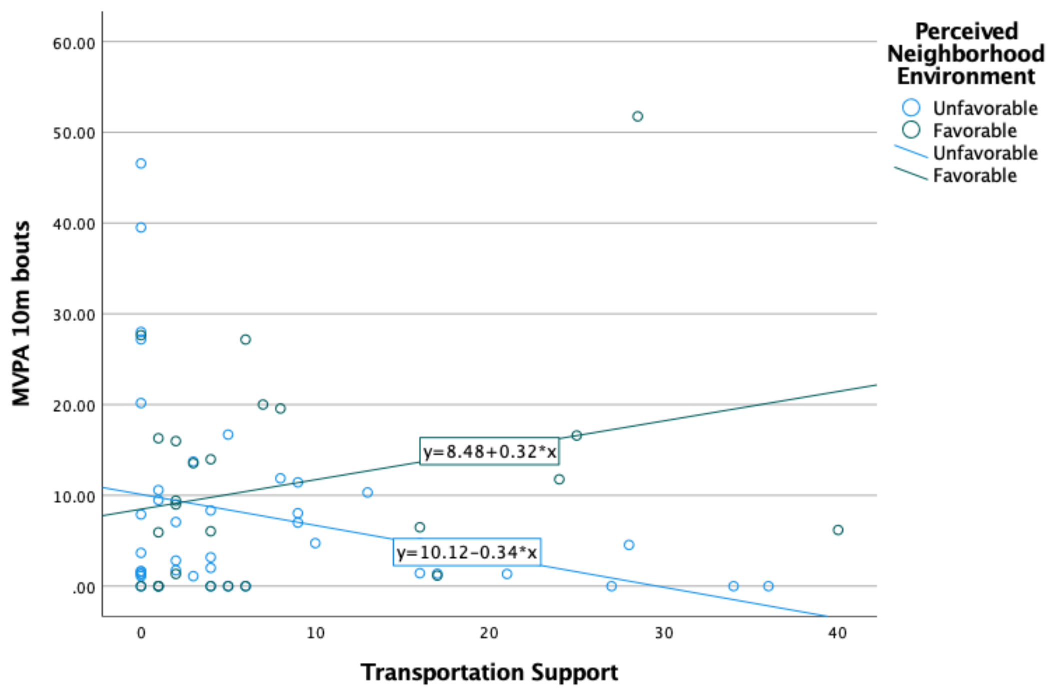

Figure 7: Main moderation analyses examining parent-perceived neighborhood environment as a moderating variable in the relationship between total transportation support and child 10-minute MVPA bouts (mean mins/day).

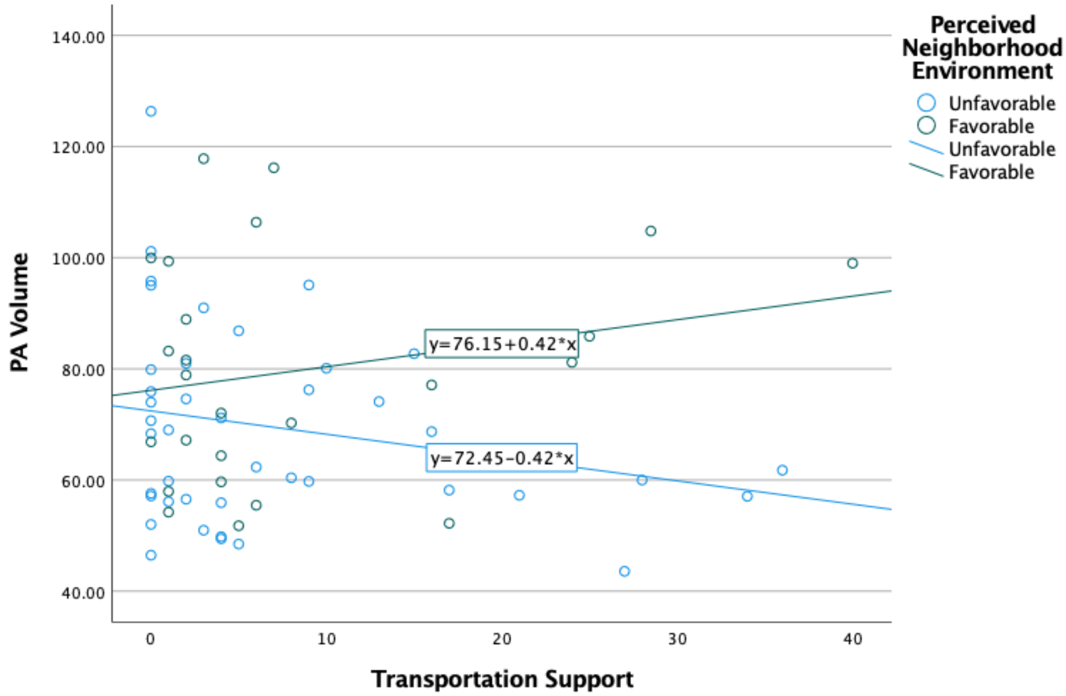

Figure 8: Main moderation analyses examining parent-perceived neighborhood environmental attributes as a moderating variable in the relationship between total transportation support and child PA volume (mean mg/day).

Moderating Impact of BMI Percentile on Additional Child Activity Outcomes

Hierarchical multiple regressions were performed to explore the impact of child BMI-for-age-and-sex percentile as a moderating variable in the relationship between parent transportation support and child PA. To test moderation, we looked at the interaction between total transportation support and child BMI and whether or not such an effect was significant in predicting child activity: sedentary time (mean mins/day), light PA (mean mins/day), MVPA (mean mins/day), 1-5-minutes MVPA bouts (mean mins/day), 5-10-minute MVPA bouts (mean mins/day), 10-minute MVPA bouts (mean mins/day), and PA volume (mean mg/day). The results from the main moderation analyses performed using the PROCESS procedure in SPSS are shown in **Table 22**. Child BMI percentile moderated the

Table 22: Main Moderation Analyses Exploring Child BMI Percentile as a Moderator in the Rlationship between Total Transportation Support and Additional Child Activity Outcomes

Model	β	SE	*t*	*p*	95% CI Lower	95% CI Upper
Sedentary Time [a]						
Constant	598.27	7.71	77.57	<.001	582.81	613.62
Support	-.40	.72	-.55	.59	-1.82	1.04
BMI	.05	.27	.16	.87	-.50	.59
Support x BMI	.01	.04	.24	.81	-.07	.08
Light PA [b]						
Constant	225.66	3.92	57.64	<.001	217.84	233.48
Support	-.07	.38	-.17	.86	-.82	.69
BMI	.27	.12	2.27	.03	.03	.50
Support x BMI	-.01	.01	-.94	.35	-.03	.01
MVPA [c]						
Constant	103.53	3.48	29.79	<.001	96.59	110.47
Support	-.13	.39	-.33	.75	-.90	.65
BMI	-.17	.13	-1.31	.20	-.44	.09
Support x BMI	.01	.02	.51	.61	-.03	.05
$MVPA^{1\text{-}5mbts}$ [d]						
Constant	23.58	1.13	20.90	<.001	21.32	25.83
Support	-.03	.11	-.31	.76	-.25	.18
BMI	-.08	.05	-1.68	.10	-.18	.02
Support x BMI	.001	.01	.10	.92	-.01	.01
$MVPA^{5\text{-}10mbts}$ [e]						
Constant	5.37	.53	10.23	<.001	4.32	6.42
Support	.01	.06	.10	.93	-.11	.12
BMI	-.03	.02	-1.50	.14	-.07	.01
Support x BMI	.04	.002	2.27	**.03**	.001	.01
$MVPA^{10mbts}$ [f]						
Constant	9.42	1.34	7.05	<.001	6.75	12.09
Support	.02	.19	.08	.94	-.36	.39
BMI	-.12	.05	-2.53	.01	-.22	-.03
Support x BMI	.01	.004	2.48	**.02**	.002	.02
PA Volume [g]						
Constant	73.71	2.13	34.61	<.001	69.45	77.96
Support	.004	.22	.02	.99	-.44	.44
BMI	-.20	.09	-2.31	.02	-.37	-.03
Support x BMI	.01	.01	1.13	.26	-.01	.03

[a] R= .09, R^2= .01, F(3, 64)= .12, p= .95. [b] R= .23, R^2= .05, F(3, 64)= 1.73, p= .17. [c] R= .19, R^2= .03, F(3, 64)= .81, p= .49. [d] R= .23, R^2= .05, F(3, 64)= 1.00, p= .40. [e] R= .32, R^2= .10, F(3, 64)= 1.86, p= .15. [f] R= .40, R^2= .16, F(3, 64)= 2.92, p= .04. [g] R= .33, R^2= .11, F(3, 64)= 2.23, p= .09.

relationship between 5-10-minute MVPA bouts (p= .03) and 10-minute MVPA bouts (p= .02). Greater transportation support was associated with higher 5-10-minute MVPA bouts (**Figure 9**) and with 10-minute MVPA bouts (**Figure 10**) among children with overweight/obesity.

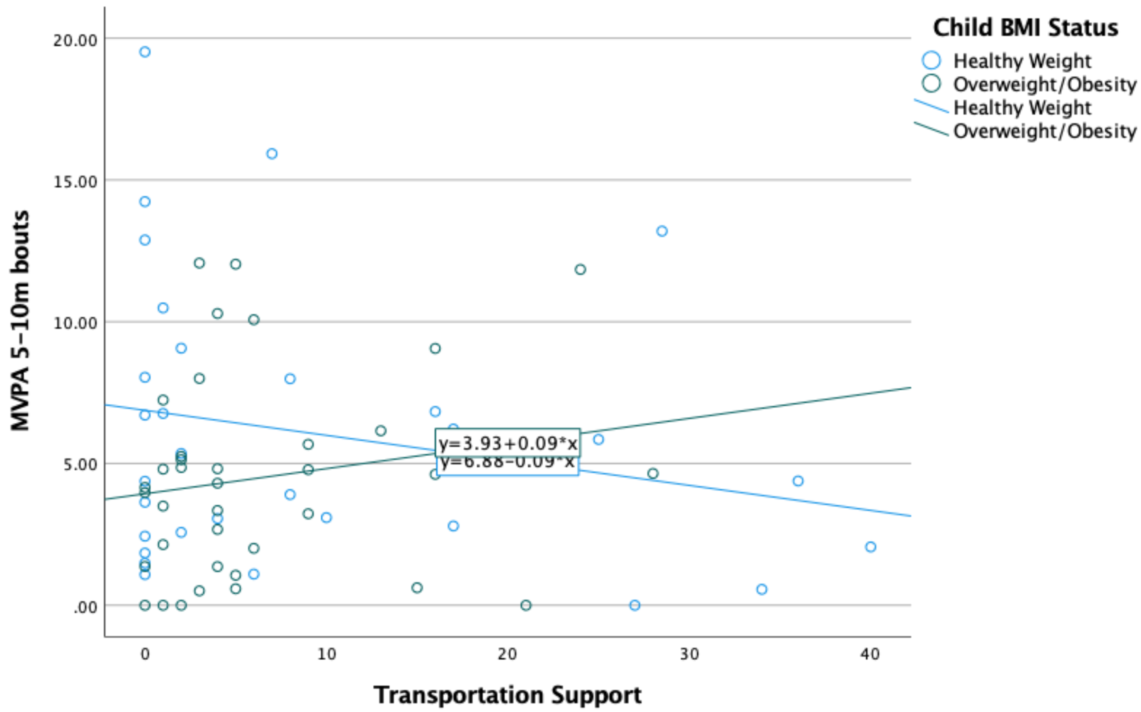

Figure 9: Main moderation analyses examining child BMI-for-age-and-sex percentile as a moderating variable in the relationship between total transportation support and child 5-10-minute MVPA bouts (mean mins/day).

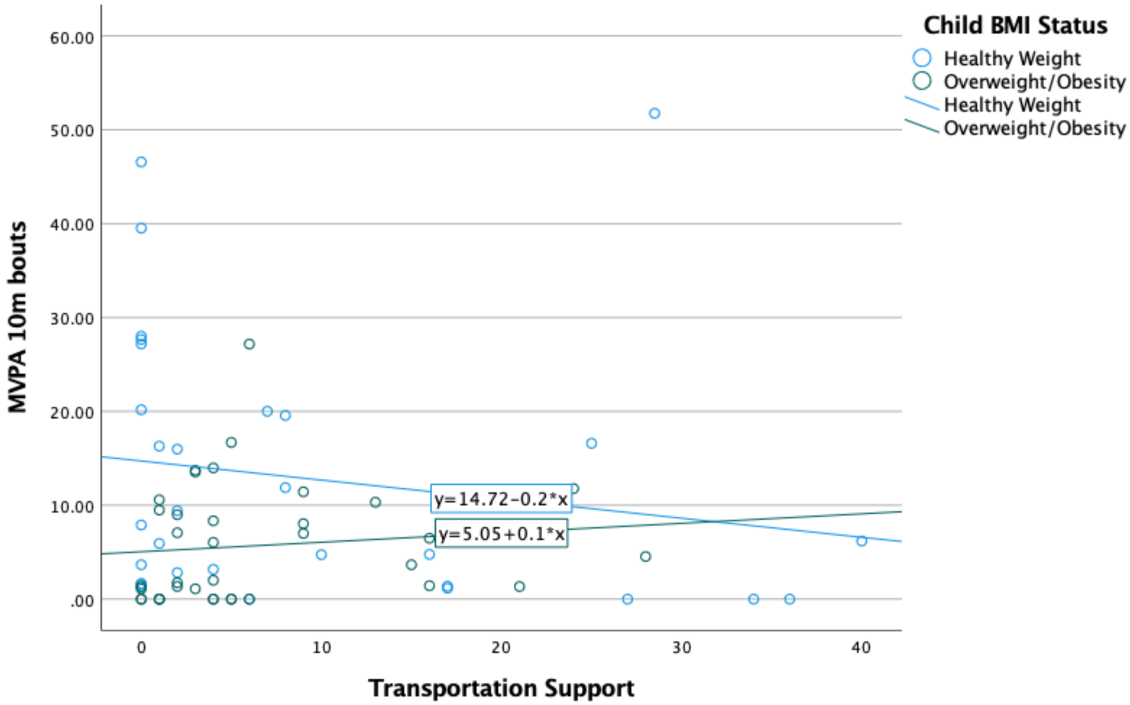

Figure 10: Main moderation analyses examining child BMI-for-age-and-sex percentile as a moderating variable in the relationship between total transportation support and child 10-minute MVPA bouts (mean mins/day).

DISCUSSION

Summary of Key Findings

This study described objectively-measured PA levels and patterns and assessed socio-environmental influences on PA among a small group of underserved preadolescent youth taking part in a community-based, family-focused behavioral intervention. This study has five key findings. First, children spent 65% of their waking time at a sedentary level and 11% in MVPA. Second, 50% of children met the recommended PA guidelines of ≥ 60 minutes of daily MVPA. Third, girls were more physically active than boys, and younger children were more active than older children. Fourth, parent-perceived neighborhood environment, not transportation support, influenced child PA. Fifth, perceived neighborhood environment and BMI moderated the relationship between total transportation support and exploratory PA outcomes. This chapter expands on these findings and makes comparisons to findings from other accelerometer studies in youth, discusses the significance and impact of these findings, describes study limitations, and provides recommendations for future research.

Accelerometer-Measured Child Activity (Aim 1)

The primary aim of this study was to characterize and describe various domains of accelerometer-measured PA (sedentary time, total PA, PA intensities, average acceleration) and examine differences by child age, sex, and weight status. We assessed four measures of MVPA to differentiate average minutes per day spent in MVPA (total, non-bout), sporadic bouts (1-4 consecutive minutes in MVPA intensity), short bouts (5-9 consecutive minutes in MVPA intensity), and medium-to-long bouts (10 or more consecutive minutes in MVPA intensity). Based on the existing youth PA literature, we hypothesized that (1) participants in this sample would be insufficiently active; (2) participants would be less active on weekends compared to weekdays; (3) a small proportion of participants would meet current MVPA guidelines; and (4) PA levels would be greater among participants who were younger (vs. older), boys (vs. girls), and had healthy weight (vs. overweight/obesity). Consistent with the overall youth PA literature, increased sedentary time was negatively associated with total PA, light PA, MVPA, and PA volume,[11,41,56,74,214,231] and PA volume was strongly, positively correlated with MVPA.[41,46,232] The four MVPA measures (mean MVPA, sporadic MVPA bouts, short MVPA bouts, and medium-to-long MVPA bouts) were significantly associated with each other,[34,233] with medium to strong correlations ranging from 0.45 to 0.91. Similar to previous studies, the strongest correlation was between total MVPA and sporadic bouts (r= 0.91), compared to the correlations between total MVPA and short (r= 0.72) and medium-to-long (r= 0.64) bouts.[34]

Frequency and Duration of Physical Activity

Participants spent an average of 8.5 hours/day in sleep period time and 15.5 hours/day in waking time. As hypothesized, the majority of participants' waking time was spent sedentary (65%). The average minutes accumulated in sedentary time (598 min/day) in this sample is higher than national accelerometry data, which shows that youth ages 6-17 years spend approximately 402 to 408 min/day in sedentary behavior (approximately 50-52% of waking time).[16,50] Other national and international samples of youth ages 5-17 years have also found lower average sedentary times ranging between 308 min/day and 517 min/day.[30,60,78,90,234] The mean sedentary value in the present study is similar to recent international and national accelerometer studies. A study among 826 children (aged 8-11 years) in Ireland using wrist-worn GENEActiv monitors found that youth spent an average of 515 min/day in sedentary time (61% of waking time).[75] And another study using GENEActiv with 1261 youth in Australia found that children (aged 11-12 years) spent an average of 681 min/day in sedentary time.[51] Our findings are also similar to studies using hip-worn

ActiGraph monitors. Altenbrug's study of 902 children (aged 6-12 years) in Denmark found that children accumulated an average of 533 min/day of sedentary time.[76] Bachner's study in 425 girls (aged 11-12 years) in Germany found that 66.3% of wear time was spent in sedentary behavior.[78] A study by Evenson and colleagues with 1466 children and adolescents found that youth (aged 8-16 years) spent an average of 605 min/day in sedentary time. Trost and colleagues found that children in their sample (aged 9-12 years) were sedentary for 63% of the time (approximately 516 min/day).[12]

During waking time, participants spent an average of 5.5 hours per day in total PA (i.e., approximately 329 min/day of light, moderate, and vigorous intensity activity). Similar to national accelerometry data,[16] the majority of active time was spent at a light intensity (226 min/day), as hypothesized. This finding is consistent with previous studies that used wrist-worn GENEActiv monitors with preadolescent youth.[75,214] Antczak's study of 1059 children (aged 8-9 years) in Australia found that youth accumulated 214 min/day in light PA,[214] while another sample of 826 children (aged 8-11 years) in Ireland accumulated an average of 235 min/day in light PA.[75] Our findings are also consistent with other accelerometer studies among youth (ages 6-17 years) using hip-worn activity monitors which found that youth spend between 196 and 257 min/day in light intensity PA.[12,16,76,117]

Our finding that participants spent roughly 11% of their waking time in MVPA (103 mins/day) is also consistent with recent research.[56,75,234] Keane and colleagues found that children (aged 8-11 years) accumulated an average of 91 min/day of MVPA, as measured by the wrist-worn GENEActiv accelerometer.[75] In a study of 374 Hispanic/Latino youth (aged 8-11 years), Gu et al.[56] found that boys and girls spent an average of 102 min/day in MVPA, as measured by hip-worn Actical monitors. And a study among a small sample of Portuguese children (aged 10-13 years) found that average MVPA ranged between 99 and 153 min/day, as measured by the hip-worn ActiGraph monitor.[234] On average, participants spent 24 min/day in sporadic MVPA bouts (lasting ≥ 1 and < 5 minutes), and MVPA minutes decreased with longer bout durations, with children averaging 5 min/day in MVPA bouts lasting ≥ 5 and < 10 minutes and 8 min/day in MVPA bouts lasting ≥ 10 minutes. Roughly 23% of total MVPA was spent in sporadic bouts, 5% in short bouts, and 9% in medium-to-long bouts. This finding is consistent with nationally representative accelerometer data. In a sample of 3165 children and adolescents (aged 6-18 years) from the 2003-2006 NHANES study, youth spent a greater proportion of total MVPA in sporadic bouts, compared to short and medium-to-long bouts.[35] Similarly, Willis, in a study of 396 children (aged 6-9 years) in the U.S., found that the majority of the time in MVPA bouts was spent in those lasting less than 5 minutes compared to long bout durations.[92]

Overall, participants averaged 73.2 mg/day of dynamic PA acceleration. The average volume of activities accumulated over 24-hour cycles (i.e., during sleep period time and waking time) was 48.5 mg/day. Recent research studying the utility and interpretation of accelerometer metrics indicate that any time accumulated above 100 mg (i.e., above the intensity of a slow walk) is considered "active time".[46,235] As such, the average acceleration found in our study is representative of sedentary-to-very low activity, as the mean value did not exceed the 150 mg threshold representing MVPA.[47,81,207] Recent accelerometer studies with youth using wrist-worn monitors have found similar average acceleration values among youth aged 8-13 years: 41.6 mg,[236] 45.4 mg,[232] and 45.8 mg.[235]

Variations by Weekdays vs. Weekend Days

Participants engaged in significantly more PA on weekdays (Monday-Friday) compared to weekend days (Saturday-Sunday), which is similar to previous PA studies.[78-81] During weekdays, children accumulated 25 more minutes of total PA, 16 more minutes of light PA, 11 more minutes of MVPA, and 4 more minutes of sporadic (< 5-min) MVPA bouts compared to weekend days. The average magnitude of dynamic acceleration during waking time decreased slightly on weekends, with average PA intensity shifting from a light PA level (50.3 mg/day) to a sedentary level (44.7 mg/day). In a nationally representative sample of 2737 children aged 6-years from the 2003-2006 NHANES study, median MVPA was 47.5 min/day on weekdays compared to 35.5 min/day on weekend days.[79] An international systematic review of 37 studies examining accelerometer-measured PA among school-aged children also found that children exhibited, on average, 82 min/day of MVPA on weekdays compared to 68 min/day on weekend days.[80] Sanders, in a study of 930 older predominantly Hispanic/Latino adolescents aged 13-18 years, found that participants were less active on the weekend than they were during the week.[81] These findings and those from other studies suggest that targeting weekend PA could be an important avenue for future interventions as various dimensions of youth PA were lower on weekends than on weekdays.

Adherence to Physical Activity Guidelines

We estimated adherence to current PA guidelines, defined as achieving 60 minutes or more of MVPA on all days of the 7-day measurement period.[7] In this study, 50% of participants met MVPA guidelines, which is higher than national accelerometry data[9] and global youth PA trends.[4] Yet, the proportion of children meeting MVPA guidelines in our study is similar to findings from a recent study among 9-10-year-old children in the U.K. which found that 50.3% of participants engaged in at least 60 minutes of MVPA per day.[232]

Recent accelerometer studies among youth using the wrist-worn GENEActiv monitor have also applied the 7-day measurement period guideline to their samples.[58,75,81,206] These studies found that the MVPA guidelines were met by 86.9% of children aged 9-10 years,[206] 32% of children aged 10-12 years,[58] 22.1% of children aged 8-11 years,[75] and 35% of adolescents aged 13-18 years.[81] A recent study with Hispanic/Latino youth (ages 8-11 years) found that the majority of children met MVPA guidelines per day during school hours.[56] On the other hand, the prevalence of children achieving 60 minutes or more of MVPA on all 7 days is lower in studies using hip-worn ActiGraph devices: 5% of children aged 6-8 years,[168] 11% of children aged 10-12 years,[171] and 7.6% of youth aged 8-17 years.[34] Further, we found that among participants who did not meet the MVPA guidelines on all 7 days, the average number of days in which they achieved at least 60 minutes of MVPA was 5.9 days. This means that 54 children in this sample (79.4%) achieved ≥ 60 minutes of MVPA on at least 5 days. This rate is higher compared to other accelerometer studies that define meeting PA guidelines as achieving ≥ 60 minutes of MVPA on at least 5 of 7 days: 42% in 6-11-year-olds and 8% in 12-15-year-olds;[9] 42% in children 6-11 years,[48] and 21% in children 6-8 years.[168]

Differences by Child Characteristics

As hypothesized, younger participants (aged 6-9 years) in our study were less sedentary and more active compared to older participants (aged 10-12 years). After controlling for sex and BMI percentile, age had moderate-to-large effect on child activity, explaining 13.1% of the variance in sedentary time, 15.6% of the variance in 1-5-minute MVPA bouts, and 16.3% of the variance in PA volume. On average, older children accumulated 48 more min/day in sedentary time compared to younger children. On the other hand, younger children accumulated an average of 7 more minutes of sporadic MVPA bouts (lasting ≥ 5 and < 10 minutes) per day and had a higher average PA volume compared to older children (80 mg/day vs. 65 mg/day). Significant age differences in child sedentary and PA time are largely consistent with previous accelerometer-based studies with youth in the U.S.[101] A recent study by Evenson and colleagues with 1466 Hispanic/Latino youth (aged 8-16 years) found that higher levels of MVPA occurred among 8-10-year-olds than 15-16-year-olds. Conversely, higher levels of sedentary behavior occurred among 15-16-year-olds than 8-10-year-olds.[49] Another a large population-based study with 3106 youth found that 6-11-year-old children spent more time in MVPA than 12-15-year-olds (88 min/day vs. 33 min/day, respectively).[237]

Contrary to our hypothesis, we found that girls were generally more active than boys. Bivariate analyses indicated that girls spent more time than boys in total MVPA (110 min/day vs. 94 min/day), sporadic MVPA bouts (26 min/day vs. 21 min/day), short MVPA bouts (6 min/day vs. 4 min/day), and medium-to-long MVPA bouts (12 min/day vs. 5 min/day). After adjusting for age and BMI in MANOVA analyses, we found that sex had moderate-to-large effect on child activity, explaining 13.6% of the variance in short MVPA bouts, 13.9% of the variance in medium-to-long MVPA bouts, and 11.8% of the variance in PA volume. Compared to boys, girls accumulated 3 min/day more of short MVPA bouts and 7 min/day more of medium-to-long MVPA bouts. Girls also had a higher PA volume compared to boys (78 mg/day vs. 67 mg/day, respectively). Our findings are largely inconsistent with those from previous accelerometer studies that have found that boys are more physically active than girls,[11,25,35,63,109,238] spend more time in

MVPA,[12,34,48,50,58,75,90,168,178,187,196,239,240] participate in longer bouts of MVPA,[34,35,48] and have higher PA volume (mg)[232] compared to girls.

We know of one other study that has found high PA levels among girls. Bachner's recent study with 425 adolescent girls (aged 11-12 years) found higher accelerometer-based MVPA values compared to other international studies, with girls accumulating an average of 82 min/day of MVPA (approximately 1.4 hours/day), and over 90% meeting recommended PA guidelines.[78] However, this study included only girls so a comparison to their male counterparts could not be made. Few other studies have found higher PA levels among girls compared to boys. Silva's study with Portuguese youth (aged 10-13 years) examined seasonal variations in MPVA between boys and girls and found that, although boys accumulated more MVPA minutes in the summer (153 min/day vs. 127 min/day), girls accumulated more MVPA minutes during the winter (121 min/day vs. 99 min/day).[234] Gender differences in seasonal PA patterns were explained by differences in choices of outdoor vs. indoor PA, where boys reported less outdoor play and more sedentary behavior during the winter and girls reported smaller seasonal differences.[234] Similar to our findings, Mark and Janssen's study of 2498 youth aged 8-17 years found that girls spent a higher amount of time in sporadic MVPA bouts (lasting ≥ 1 and < 5 minutes) compared to boys (i.e., 71.7% vs. 60.4% of total MVPA).[34] Willis' study of 396 children ages 6-9 years also found that, compared to boys, girls spent more time in sporadic MVPA bouts per day. Specifically, girls spent 92.4% of their overall MVPA time in sporadic bouts, while boys spent 89.3% of their overall MVPA time in sporadic bouts.[92] And another study with 26 children (aged 8-10 years) in France found that girls spent more time in light PA compared to boys (763 min/day vs. 745 min/day), although boys spent more time in vigorous intensity (17.2 min/day vs. 11.6 min/day).[241]

Our finding that girls in this study were more physically active than boys was surprising. It is possible that our results are being driven by a selection bias of healthy, active girls who chose to enroll in the *Athletes for Life* study. Knowledge about the physical contexts (e.g., indoor/outdoor locations), domains (e.g., leisure, transportation, school), and types (e.g., jumping rope, running, playing sports) of participants' activity would provide a better understanding of the PA behaviors of girls in this sample and may also help explain this finding.[124,128,242,243] For example, a study among 374 Portuguese children (mean age 11.7 years) showed significant gender differences in domain-specific time spent in MVPA.[244] They found that the transportation domain had the largest proportion of accelerometer-measured MVPA bouts compared to the home, school, and leisure domains. Moreover, 54.4% of girls' MVPA was in the transportation domain (compared to 35.2% of boys' MVPA), and most of boys' MVPA was in the school and leisure domains.[244] Other studies also found that girls accumulate a significant amount of light PA during leisure time and more MVPA time in active transport (e.g., walking or biking), at home, in shopping locations, and when visiting parks.[184,242,245-247] Based on these earlier studies, it is possible that girls in our sample may have accumulated more PA in specific contexts, domains, or types of activities such as assisting with chores at home,[248] taking dance classes,[249] or walking to-from school,[128] compared to boys, although this cannot be determined as this data was not collected as part of the larger *Athletes for Life* study.

Nevertheless, our finding that girls were more active than boys is perhaps indicative of ongoing national and global efforts to improve PA among girls.[250-255] Studies of nationally representative samples of U.S. youth have identified sex-specific subgroup trends in adolescents' PA which suggest changing disparities.[10,109] A study of Youth Risk Behavior Survey (YRBS) data (1991-2007) examined sex, age, and racial/ethnic differences in the patterns and time trends of adolescents' self-reported PA. The study found that Hispanic girls experienced a steady improvement in 'sufficient moderate PA' between 1999 and 2005. The prevalence of 'sufficient moderate PA' increased from 17% to 24%, while prevalence of 'insufficient PA' declined by an average annual rate of 1.2%.[109] A more recent study of 2009-2019 YRBS data found that, although adolescent self-reported PA has declined among both boys and girls, the greatest declines in the percent of youth meeting guidelines are among adolescent boys. Hispanic boys also showed decreasing trends in meeting PA guidelines (for aerobic and muscle-strengthening activities) and sports participation, compared to Hispanic girls, although these trends appear to be indicative of worsening PA patterns among boys and unimproved patterns among girls.[10] Similar trends were found in a recent sample of 7827 Spanish adolescents and young adults in which the PA levels of boys declined to a greater extent compared to their female counterparts.[256]

As hypothesized, participants with overweight/obesity were generally less active compared to those with healthy weight, which is consistent with previous accelerometer studies.[11,75,133] Bivariate analyses indicated that healthy weight children accumulated significantly more minutes in medium-to-long MVPA bouts and had higher PA volume compared to children with overweight/obesity, although these associations remained marginally significant after adjusting for age and sex. Our findings are similar to earlier studies. Willis and colleagues found that school-aged children (ages 6-9 years) who had a higher percentage of short (5 to <10 min) and medium-to-long (≥ 10 min) bouts (14%) had significantly lower BMI percentile than children who had a lower percentage (3.2% of short and medium-to-long bouts.[92] A study by Deforche and colleagues study in a sample of 120 Finnish children (aged 6-10 years) also found that children with overweight/obesity spent significantly less time in medium-to-long (≥ 10 min) MVPA bouts than children with healthy weight.[257] Mark and Janssen's study of a nationally representative sample of 2498 children and adolescents in the U.S. also found that the time spent in medium-to-long MVPA bouts (≥ 10 min) was significantly, negatively related to the odds of overweight.[34] And Fairclough's study in a sample of 195 children (aged 9-10 years) found significant differences in PA volume (mg/day) by child weight status.[232] Similar to earlier studies, we found no significant differences in light PA[257] or sedentary time[75,104,257] by child weight categories. However, contrary to previous studies, we found no significant differences in total MVPA by child weight status.[81,104,257,258] We found a significant interaction between sex and BMI weight status for medium-to-long MVPA bouts (≥ 10 min), suggesting that the influence of weight status on time spent in medium-to-long MVPA bouts is significantly different for boys than it is for girls (**Figure 3**). That is, girls with healthy weight spent substantially more time in MVPA bouts ≥ 10 minutes compared to healthy weight boys and compared to children with overweight/obesity.

Significance and Impact of Findings (Aim 1)

One of the most important limitations in studies of correlates of youth PA is that they rely on child or parent reports of child activity.[22,25,259,260] The present study used high frequency acceleration data to examine the accumulation of PA in a free-living setting, which has been done in few studies among underserved youth.[26,261] Accelerometers have shown acceptable validity and reliability[210,222,262,263] and are recognized as accurate objective instruments for PA measurement among various populations.[264,265] This study's PA outcomes were generated through an analysis that followed the most recent recommendations of accelerometer-related literature.[81,217,218,223] We also used the GGIR open-source program to summarize raw accelerometer PA data, as done with recent accelerometer studies with youth samples.[36,46,47,81,205-208,212,214,216,221,222,232,235,236,239,263,266] This allows us to compare our results to other studies that followed these recommendations and processing criteria. Moreover, the use of accelerometry will allow comparison of our sample with national accelerometry data and with findings from other studies in which accelerometry has been used as an objective measure of youth PA.

Overall, our results indicate that underserved, predominantly Hispanic/Latino youth, living in a low-income environment had higher levels of PA and sedentary behavior than national averages.[5,9,16,50] It is possible that the wrist-worn accelerometers used in our study captured higher quantities of activities, compared to hip-worn devices used in previous studies. Research indicates that raw acceleration values from wrist-worn accelerometers are normally higher compared to waist- or hip-worn accelerometers. Wrist-worn accelerometers are positioned to capture upper extremity movements which may not be identified by hip-worn accelerometers[81,206,207,213,267] for instance, non-ambulatory movements (e.g., arm movement when seated such as writing or grooming) or other upper body activities.[210] A study by Fairclough and colleagues examining differences in raw counts of PA between wrist-worn and hip-worn accelerometers, found that raw data from wrist-worn GENEActiv indicated that 87% of children engaged in at least 60 minutes of MVPA, compared to 19% for children who wore the hip-worn ActiGraph device.[206] Bianchim and colleagues also found significantly higher PA outputs from wrist-worn GENEActiv devices, compared to

ActiGraph devices worn at the hip, particularly during activities of vigorous intensities.[266] In our study, MVPA values are generally higher than those reported by previous studies using hip-worn accelerometers.[16,50,60,79,117,126,143,168,187,240]

We found good accelerometer compliance in our study sample which may also be influencing our PA outcomes. Higher wear compliance naturally leads to the assessment of more days of PA and capture of a greater proportion of activity each day.[268] Participants were asked to wear the accelerometers for 7 consecutive days, 24 hours per day. The majority of participants wore the accelerometer for the full measurement period (average 6.9 days, 11 hours/day), which is consistent with previous youth PA studies using wrist-worn GENEActiv monitors,[208,233,236] but higher compared to studies using hip-worn accelerometers.[12,92] Accelerometer compliance could be attributed to the waterproof feature of the accelerometers, which allowed participants to continue wearing the device during swimming activities or showering, whereas with hip-worn accelerometers, the device would have been removed for these activities.[269] As such, the wrist-worn accelerometers in this study may have captured activity for larger amounts of time, which would naturally yield higher PA values than studies with less average wear time. Additionally, accelerometer compliance in our sample could be related to a motivated study population who had been recently enrolled in the *Athletes for Life* 12-week fitness- and nutrition-focused project and, as such, may have been more inclined to be engage in healthy behaviors (i.e., be more active than usual). Nonetheless, high accelerometer compliance results in longer monitoring periods which are associated with more consistent measures of activity.[36] Research shows that between 3 and 6 days of accelerometer measurement are needed to achieve good reliability of youth PA and sedentary behavior measurement using wrist-worn GENEActiv accelerometers.[36,263] Thus, the good compliance found in our study provides confidence that the data are representative of daily activity for children in our sample.

Yet, comparing the PA values found in this study with earlier studies is challenging due to the variety of monitors used in PA research, such as brands (e.g., GENEActiv, ActiGraph, Actical), acceleration panes (e.g., uniaxial vs. triaxial), and body placement (e.g., wrist, hip, ankle). Accelerometer methods are also highly variable between studies using the same device and there is a lack of consistency in decision rule reporting for processing raw, high-frequency accelerometer data.[53,270,271] Estimates of PA and sedentary behavior vary depending on sampling frequency, epoch length, and activity cut points applied to raw accelerometer data.[215] For example, when we compared our study's PA findings with those from other studies using wrist-worn GENEActiv monitors with preadolescent populations, we found that we obtained lower mean sedentary values,[51,209,214] lower average acceleration values,[233] and higher total MVPA values.[51,58,81,206,212,214,239] However, there is a lot of variability in the processing criteria for these studies (See Appendix **Table 25**). As such, inferences made regarding youth PA behavioral patterns in this study may depend upon the chosen data processing methods.

Our study's accelerometer data were collected at a sampling frequency of 40 Hz over 5-second epochs as part of the protocol of the *Athletes for Life* project. We processed raw data using the GGIR open-source software[217] and used PA intensity thresholds based on studies among youth aged 9-14 years.[47,207] The sampling frequency we used is substantially lower than previous accelerometry studies with youth, which range between 30 Hz and 100 Hz, with most studies using higher sampling frequencies such as 85.7 Hz or 100 Hz.[43,46,47,54,59,75,205,206,209,211-214,216,233,239,262,263,266,270] (See Appendix **Table 25**). Migueles' systematic review of processing criteria for ActiGraph accelerometers found that sampling frequencies at 40 Hz have resulted in an increased number of activity counts in previous studies and recommend that researchers use the highest frequency possible, such as 100 Hz, when filtering and processing raw accelerometer data.[223] Our use of 5-second epochs may have also detected additional, shorter patterns of PA, especially among younger children. A recent study by Altenburg and colleagues examined the influence of using different epoch lengths (5-, 15-, and 60-seconds) on the classification accuracy of free-living total MVPA, time spent in MVPA bouts, and sedentary time among 902 children in Denmark. They found that total and sporadic MVPA decreased using longer epochs (60-seconds) and their findings suggest that a substantial amount of light PA was classified as sedentary behavior when using shorter epochs (5- and 15-seconds).[76] As such, it is possible that by using a shorter epoch length in our study, we could have overestimated MVPA values and/or have light PA classified as sedentary behavior.

Additionally, the prevalence of meeting MVPA guidelines can vary depending on the cut points used.[272] In our study, the proportion of participants who met MVPA guidelines was higher than the national average. We applied PA thresholds for wrist-worn GENEActiv accelerometers which defined MVPA as time accumulated above an acceleration of 150 mg.[47,207] More recent studies have used a threshold of 192 mg to classify MVPA, although these studies used different sampling frequency criteria than our study,[214,262] and research generally proposes an MVPA threshold of 192 mg based on 60-second epochs.[239] The likelihood of capturing higher MVPA values in our study through our use of the 150 mg threshold is of minimal concern, as no participants in our sample averaged 150 mg on any day throughout the full measurement period.

The findings from our primary analyses add to the limited literature available on raw accelerometer data of low-income, primarily Hispanic/Latino preadolescent youth in the U.S., as measured by wrist-worn GENEActiv monitors. Despite the fact that we used a lower frequency and shorter epochs for raw accelerometer data processing, the mean values obtained for sedentary time, light PA, MVPA, and PA volume are in line with earlier studies. We followed previous recommendations calling for the use of shorter epochs for the study of raw accelerometer data of children ages 6-12 years,[11,36,46,47,81,101,215,222] applied evidence-based PA cut points derived from raw accelerations,[47,207] and estimated various dimensions of free-living PA (frequency, intensity, bouts, duration, PA volume). As such, our study provides novel information about accelerometer-measured PA and sedentary behavior among underserved pre-adolescent youth. PA is a complex, multidimensional behavior, and no single measure can assess all its constructs.[27] The use of cut point-based PA intensities helps researchers characterize the amount of time that youth spend in various levels of activity during waking time. Each level of PA intensity conceptually represents a different behavior with potentially unique determinants and establishing their impact on youth health outcomes has significant clinical implications.[55] Recent developments in PA measurement techniques are allowing researchers to capture more detailed objective data, allowing for an improved understanding of the accumulation and patterns of youth activity. PA volume (i.e., average acceleration) is a novel measure that provides an additional description of children's PA profile by taking the frequency, intensity, and duration of periods of activity and summarizing them into a single metric (i.e., total PA, mg); thus, providing complementary information about how much activity children are averaging over a 24-hour cycle.[46,47]

One advantage of using the PA volume metric is that it allows comparisons between studies using raw acceleration signals, which could lead to improved recommendations for youth PA.[46,273] One example is a recent study by Fairclough and colleagues among 9-10-year-old children in the U.K. They found that children spent the majority of the day at a sedentary level, yet 50% of participants met the daily MVPA recommendations, averaging 64 min/day of MVPA. The average PA volume in their sample of was 45.4 mg (i.e., mainly sedentary). Their findings suggested that increasing PA volume by simply moving more, regardless of intensity, was positively associated with children's health-related quality of life.[232] The authors applied a procedure described by Rowlands[46] for translating PA volume into meaningful public health recommendations, which indicated that Fairclough's study sample would need to replace time spent at their average acceleration (45.4 mg/day) with brisk walking for 2 hours, slow running for 24 minutes, or medium running for 19 minutes, accumulated across the day, to increase their average acceleration by 1 standard deviation.[232]

Similarly, our study found that participants spent almost 10 hours/day in sedentary intensity, a smaller proportion of time in light PA intensity, and even less time in MVPA intensity. Yet, 50% of participants achieved ≥ 60 minutes of MVPA on all days, while 79% achieved ≥ 60 minutes of MVPA on at least 5 days. Average PA volume provided us with additional information about our study sample, indicating that participants mainly engaged in sedentary activities (M±SD= 48.5±11.5 mg), despite averaging 103 min/day of MVPA. Like Fairclough's study,[232] our findings indicate that children can spend a high proportion of time being sedentary and still meet MVPA guidelines. However, the average amount of time participants spent in sedentary behavior is concerning given the evidence of the associations between sedentary behavior and the increased risk for obesity[8] and other negative health outcomes.[17,274-277] A fitting intervention for this population would, therefore, focus on decreasing sedentary behaviors in addition to promoting PA. Previous research suggests that once adequate MVPA recommendations are met in a given day, health benefits can still be achieved by reducing time spent sedentary and allocating more time to light PA.[55] As such, we could potentially use the information obtained from the PA volume metric and make specific PA recommendations for this population. For example, to increase their average acceleration by 1 SD (i.e., 11.5 mg), participants would need to replace time spent at the average acceleration (i.e., 48.5 mg/day) with slow walking for 60 minutes (e.g., pottering around=1.1 mg), brisk walking for 60 minutes (e.g., active commuting to-and-from school=6.4 mg), and slow running for 8-9 minutes (e.g., active recess play=4.0 mg), accumulated across the day (1.1 mg + 6.4 mg + 4.0 mg = 11.5 mg) (per Rowlands' procedure).[46] These PA recommendations would involve modest changes to children's current activity that could have an important impact on their short- and long-term health. Recent evidence indicates that the reallocation of time spent in sedentary behavior to a light PA is associated with a number of positive health outcomes, such as reduced adiposity, increased cardiorespiratory fitness, and decreased mortality risk.[55,84] This is especially important in a population that experiences pervasive disparities in childhood obesity[115] and cardiometabolic risk factors.[112]

Socio-Environmental Influences on Accelerometer-Measured Activity (Aim 2)

The secondary aim of our study was to investigate the potential impact of socio-environmental factors on participant's accelerometer-measured PA. Specifically, we investigated whether the transportation support provided by parents predicted their children's total PA (i.e., light, moderate, and vigorous child activity), beyond personal variables such as age, sex, and BMI. We used total PA (mean min/day) as the main outcome in our secondary analyses because it combines the full range of PA intensities during children's waking time.[42] Moderation by neighborhood environment and child BMI were examined, given the evidence that they are important moderators on child PA.[20,141,162,174] We hypothesized that (1) parents would report greater transportation support for younger children (vs. older children) and for boys (vs. girls); (2) higher transportation support (vs. lower transportation support) would be positively associated with total PA; (3) a more favorable neighborhood environment would be positively associated with transportation support; and, (4) the relationship between transportation support and total child PA would vary depending on levels of parent-perceived neighborhood environment (favorable vs. unfavorable) and child BMI status (healthy weight vs. overweight/obesity).

The association between transportation support and total child PA was not significant in our study. No significant differences were found in transportation support between younger children and older children, or between boys and girls, as hypothesized, although results showed that parents of children with healthy weight reported providing higher transportation support compared to parents of children with overweight/obesity. We identified an inverse relationship between transportation support and child PA in our study, implying that total PA decreased as the frequency of transportation to a location for PA increased. The direction of this relationship, although not significant, was unexpected. Overall, our results indicate that, although parents reported sufficient supportive behaviors (i.e., taking their child to a location for PA approximately 8 times over the past month), transportation support did not have a significant impact on their child's total activity. Our findings are largely different from earlier research in this area. Numerous studies have consistently identified a positive association between parental support for child PA and child activity.[19,22,23,25,72,139,143,145,146,162,163,259,260] However, the majority of these studies report associations between parent support and self-reported PA outcomes.[24,260] Among studies using objectively-measured PA, findings have been somewhat inconsistent.[20,117,123,140,143,168,174,187,278-280] Two separate studies by Siceloff[281] and Peterson[282] with underserved preadolescents (aged 10-14 years) found that parental transportation support was significantly associated with youth MVPA, as measured by Actical monitors.[281,282] On the other hand, Chiarlitti's study in a sample of 7-10-year-old children found no significant relationship between parent-reported social support and child's daily steps.[278] And Dowda's study[140] of 409 children in the U.S. (mean age 10.6 years) found that parent social support was not associated with MVPA measured with ActiGraph monitors and only found significant associations with self-reported child PA and parent-reported child PA.

Overall, parents in this sample reported having a favorable neighborhood environment, with parents perceiving the presence of activity-supportive environmental attributes in their neighborhoods (i.e., walkability). In line with previous research, the total neighborhood environment mean score was just over the midpoint ($M = 2.7$),[126] and mean subscale scores found in our study are comparable to those found in earlier research with adults from low- and high-income neighborhoods.[283] In general, parents had high scores for pedestrian infrastructure (e.g., 78% have sidewalks on most streets in their neighborhoods), and crime safety (e.g., 60% did not perceive high crime rates in their neighborhoods). Conversely, parents had low scores for traffic safety (e.g., 66% reported that drivers exceed posted speed limits in their neighborhoods) and neighborhood aesthetics (e.g., 53% had interesting things to look at while walking, 56% had attractive natural sights, 59% had attractive buildings/homes). We found weak but positive associations between total neighborhood environment (r= .31), neighborhood aesthetics (r= .31), and pedestrian traffic safety (r= .29) and total child PA which is consistent with previous research.[179,183,284]

Contrary to our hypothesis, parent-perceived neighborhood environment was not significantly associated with parent support for PA transportation. Additionally, child BMI percentile was not significantly correlated with transportation support or neighborhood environment. In moderation analyses, we found that neither parent-perceived neighborhood environment nor child BMI percentile moderated the relationship between transportation support and total child PA. These findings are inconsistent with recent studies. Colibianchi and colleagues, in a racially/ethnically diverse sample of 636 children, found that children (mean age 10.6 years) in PA-supportive neighborhood environments with high parental support for PA generally maintained higher total PA levels compared with children with low parental support.[20] Another study among low-income youth in the U.S., aged 6-13 years, found that more favorable neighborhood environmental attributes (i.e., neighborhood safety) and family support for PA were associated with accelerometer-measured PA.[187] And Liszewska's study in a sample of 879 Polish children, aged 6-11 years, found that overall greater parental support predicted higher levels of child PA, and this relationship was moderated by child BMI z-score.[162]

Significance and Impact of Findings (Aim 2)

Our overall findings suggest that parent-perceived neighborhood environment, and not transportation support, had a significant effect on accelerometer-measured total child PA. Although earlier research supports the provision of parent support as a significant correlate of youth activity,[24,139,145,146] there are considerable variations in how studies have defined and measured parental social support for PA. For the most part, parent support has been assessed as an aggregate measure of supportive behaviors (e.g., encouragement, co-participation, transportation, informational, logistical, watching, praising, modeling),[24,140,143,162,174,260] with no consistency in the set of behaviors used in aggregate measures. Few studies have examined individual supportive behaviors for child PA,[20,24,170,171] and even less have investigated associations between individual supportive behaviors and objectively-measured child PA. A comprehensive meta-analysis by Yao and colleagues quantified the relationship between youth- and parent-reported parent support (overall and individual behaviors) and child PA (self-reported and objectively-measured) from 112 previously-published narrative reviews and quantitative reviews.[24] The authors found moderate effect sizes for the relationship between overall parent support and self-reported child PA (r= .38). However, when objective measures of PA were used, results showed weak effects of overall support on PA (r= .20). Further, few studies investigated transportation as an individual supportive behavior, but those that did found that transportation support had a weak effect on objectively-measured child PA (r= .14).[24]

In this study, we found that parent perceptions of more favorable, activity-supportive neighborhood environments were positively associated with total PA which, for the most part, is consistent with the broader literature in this area.[117,126,179,180,182,186,187,196,240,284-286] However, there is variability in how studies have assessed neighborhood environmental attributes (parent-reported, youth-reported, objectively-measured) and youth PA (self-report versus objective measurement). For example, a study among 928 U.S. adolescents, ages 12-16 years, found that parent-reported neighborhood walkability (measured with 3 items) predicted adolescents' accelerometer-measured MVPA.[179] Another study with 480 Hispanic parent/child dyads found that accelerometer-measured child PA was not associated with parent-perceived neighborhood crime (measured with a single item).[287] Tappe's study in a sample of 724 children, ages 6-11 years, found that accelerometer-measured PA was not associated with parent-reported neighborhood environment (measured by the NEWS-Y items).[238] And a literature review of 103 studies examining associations between objective- and perceived-neighborhood environment attributes and youth PA found that stronger evidence existed for associations involving objectively-measured environmental attributes (e.g., residential density, land-use mix) and self-reported PA.[186]

It is possible that our study may not have been sufficiently powered to detect significant associations in our moderation analyses due to its small sample size. Moderation effects are often small and may require larger samples to be detectable.[288] However, participants in the present study represent a sub-sample of a larger *Athletes for Life* randomized control trial to improve cardiovascular fitness among parent-child dyads,[204] which was not powered based on our current research question. Additionally, the standard deviation of parent's NEWS scores was almost zero; thus, the small variation in neighborhood environment may have limited the ability to observe statistically significant interactions.

Nonetheless, the findings from Aim 2 of our study add to the limited evidence base on the role of multiple systems of influence on accelerometer-measured total PA of underserved, primarily Hispanic/Latino youth in the U.S. Few studies examine associations between parent-provided transportation for PA[170] and even less have used objectively-measured total child PA.[24] Our results suggest that parents of children who are more active may perceive their neighborhood environment as safe (e.g., they may encourage their child to be active in outdoor activities), whereas parents of children who are less active may attribute their child's decreased activity to an unsafe neighborhood environment.[188] These findings point to a need to develop programs and policies that help create walkable neighborhoods that are supportive of PA in underserved communities (e.g., structured neighborhood PA programs, community policies). This is particularly important in a population that experiences economic and racial environmental disparities. Hispanic/Latino youth living in underserved communities are more likely to live in low-SES neighborhoods with higher crime and worse environmental conditions, compared to non-Hispanic/Latino white youth, likely exacerbating barriers to being active.[5,25,176,192,196-198,284] Neighborhoods with higher crime, increased traffic, and decreased places for walking may dissuade parents from encouraging their child to be active in outdoor activities, such as cycling/walking to and from school or using community recreation facilities.[21,183,185,289] Low-SES and Hispanic/Latino youth have also reported significantly less safety to walking or playing outdoors in their neighborhoods, compared to their middle- to high-SES non-Hispanic peers.[196] This has been associated with decreased PA among low-SES Hispanic/Latino youth.[196] Conversely, higher levels of pedestrian-friendly neighborhoods have been associated with higher PA among low-income, diverse youth,[126,189] and Hispanic/Latino youth engage in more PA when the quality of their neighborhood social environment was higher.[182] This emphasizes the need to target underserved youth's social environment to reduce disparities in PA. This may be through policies that create or modify PA-supportive environments to make it easier and safer for low-SES families to be active in their neighborhoods, for instance improving landscaping and lighting to enhance the aesthetics and perceived safety of the community.[290,291]

Exploratory Aim: Socio-Environmental Influences on Additional PA Outcomes

Because PA is a complex, multidimensional behavior,[27] we further explored the potential impact of transportation support, perceived neighborhood environment, and BMI percentile on additional child activity outcomes examined in Aim 1 of this dissertation (i.e., sedentary time, light PA, MPVA, MVPA bouts, and PA volume). Results showed no significant associations between transportation support and any of the exploratory PA outcomes. However, we found small -although significant- correlations between perceived neighborhood environment and sedentary time (r= -.38), light PA (r= .24), and MVPA (r= .27), which is generally consistent with previous research.[117,170,182,189,240,284] We also found small negative correlations between child BMI percentile and medium-to-long MVPA bouts (r= -.27) and PA volume (r= -.27).

Exploratory moderation analyses found significant interactions on total MVPA, MVPA bouts, and PA volume for transportation support and neighborhood environment.[20,126,187] The results suggest that youth in PA-supportive neighborhoods (i.e., favorable neighborhood environment) with higher transportation support for PA (vs. lower support) accumulated more minutes of total MVPA, sporadic MVPA bouts (≥ 1 and < 5 min), medium-to-long MVPA bouts (≥ 10 min) and had higher PA volume (mg/day). On the other hand, youth in less PA-supportive environments (i.e., unfavorable neighborhood environment) accumulated fewer minutes of total MVPA and MVPA bouts, and had lower PA volume regardless of having higher transportation support for PA. That is, even when parents provide greater transportation to locations where their children can be active (vs. lower support), children's average MVPA, MVPA bouts, and PA volume vary depending on whether parents view their neighborhoods as having favorable or unfavorable environmental characteristics.

Results also show significant interactions between transportation support and child BMI percentile on MPVA bouts and PA volume. Children with overweight/obesity with higher transportation support accumulated more minutes of short (5 to < 10 min) and medium-to-long (≥ 10 min) MVPA bouts than children with overweight/obesity with lower support. Conversely, children with healthy weight and higher transportation support accumulated *less* minutes of short (5 to < 10 min) and medium-to-long (≥ 10 min) MVPA bouts than children with healthy weight with lower support. That is, even when parents provide greater transportation to locations where their children can be active (vs. less frequent transportation), children's average MVPA bouts vary depending on whether the child has healthy weight or overweight/obesity.

It is not clear why transportation support and youth PA are inversely related when perceived neighborhood environment is low or when children have a healthy weight status. The inverse relationship between transportation support and PA was unexpected, as previous research shows that youth in more PA-supportive environments and those with increased parent support for PA generally have higher PA levels compared with youth with lower parental support.[20] This finding warrants additional exploration in future research, which is beyond the scope of this exploratory aim. Nonetheless, these exploratory findings suggest that a PA-supportive neighborhood environment, not transportation support, helps shape the PA behaviors of underserved youth. These findings provide further evidence of the complex relationships between personal, interpersonal, and socio-environmental influences on youth

PA and emphasize the importance of examining a range of objectively-measured activity behaviors in youth.

Study Limitations

The present findings should be interpreted in light of our study limitations. The main limitation of our study is the small sample size. As such, the results of the mediation analyses should be interpreted with caution. For example, the interaction between transportation support and neighborhood environment on total child PA had a moderate effect size, although the interaction was not statistically significant (Aim 2). On the other hand, in exploratory analyses, the interactions between transportation support and child BMI on short and medium-to-long MVPA bouts (Exploratory Analyses) were statistically significant but the effect sizes were very close to zero, so it is unlikely that these results have practical significance. The small study sample size also restricted our ability to control for additional potential confounders in our analyses, such as accelerometer wear time and seasons, which are known to influence child PA.[49,170,234,268] Our study also involves secondary analysis of data obtained from a small sub-sample of participants who took part in a larger fitness- and nutrition-focused randomized control trial, *Athletes for Life*. The *Athletes for Life* study was designed to test intervention effects on parent and child cardiovascular fitness,[204] and was not powered to test our specific study hypotheses. The larger *Athletes for Life* study was limited to an underserved community in South Phoenix, Arizona. Therefore, our study includes a specific sample of preadolescent youth (6-12 years, primarily Hispanic/Latino of Mexican background), which limits our ability to examine differences with other racial/ethnic groups. And although our findings are relevant for similar populations, they are not necessarily representative of other Hispanic/Latino preadolescent youth from different sub-groups (e.g., Puerto Rican, Dominican).[49] Also, most parents in this sample were mothers, limiting conclusions for fathers and for adults who are not parents.

Due to the cross-sectional nature of our study, we are only able to provide evidence of associations and not causality. Our findings provide evidence of this specific population's PA at one point in time; thus findings should be interpreted correspondingly. Furthermore, information about participants' accelerometer placement (i.e., dominant vs. non-dominant wrist) were not collected by the *Athletes for Life* study, which limits our ability to compare our results with previous accelerometer studies that have wrist-specific results.[37,266,267] Wrist placement is important as previous studies have found that the GENEActiv accelerometer yields higher ENMO (mg) values when worn on the dominant wrist.[266] This is an important factor related to accelerometer data collection which may impact sleep, sedentary time, and PA estimations.[272]

Another potential limitation in this study involves selection bias of participants in the *Athletes for Life* study. It is possible that our study sample consists of generally active youth, girls in particular, who may have been more motivated to enroll in the *Athletes for Life* study. Participant recruitment and intervention activities for the *Athletes for Life* study occurred at a community recreation center, and parent/child dyads with membership to the recreation center may have been more interested in enrolling in the study (i.e., self-selection bias). Also, children who enrolled in the study may have been already active as they had access to the recreation center, as studies show that children who use recreation facilities engage in PA more days of the week compared to children who do not use recreation facilities.[185] Therefore, the PA values found in our study sample may not be representative of other preadolescents in this community; for instance, those who may be less interested in taking part in a fitness program or whose parents may have been unavailable to co-participate with them in *Athletes for Life* program activities.

It is also possible that observed associations between youth PA and socio-environmental factors may be affected by the nature of the measurement methodologies used (i.e., measurement bias). Transportation support for child PA was measured using a single, open-ended question from the *Athletes for Life* parent survey which asked parents to report the frequency of times they took their child to one of five locations over the past month (park, sporting event, swimming, hiking, gym). As such, our findings about transportation support will not be generalizable to other studies using aggregate measures of social support for children's PA. This self-report measure is also subject to recall bias, and it is possible that parents overestimated the number of times they transported their child to a location for PA, which may explain the non-significant associations between transportation support and child PA outcomes. Further, the transportation support measure was adapted from previous studies of youth PA that asked parents to report how often they "*provided transportation so their child could go to a place where he or she can do physical activities or play sports*".[147,160,224,292] However, the adapted single-item used in the *Athletes for Life* study did not specifically ask parents if they took their child to any of the listed locations so that their child could be active. As such, it is possible that this item did not explicitly measure parent's transportation support for their child's PA, which could also help explain our study's findings.

Considerations for Future Research

Despite potential limitations, the high-frequency sampling method used in this study has generated valid data commensurate with preadolescent youth's habitual PA behavior. Our findings also highlight the importance of assessing different dimensions of accelerometer-measured youth activity. For the most part, youth PA-promoting efforts have focused on increasing MVPA (e.g., meeting MVPA guidelines). Yet, MVPA accounts for the smallest portion of the 24-hour period, even among youth who are highly active.[45] Evidence is growing on the health benefits of light PA[18,91] and MVPA bouts.[34,35,92,257] Recent research in this area has also focused on investigating associations between novel accelerometer metrics (e.g., average magnitude of dynamic acceleration) and health indicators in children.[44,46,232,236,273] The use of these methods could be applied in other larger studies to help improve the assessment of youth PA. Given the cross-sectional design of this study, longitudinal studies with larger participant samples and across a greater variety of racial/ethnic minorities, would add strength to the study findings.

More research is needed to understand the underlying causes of the patterns revealed by our study findings, for instance, the high sedentary values, the higher prevalence of PA among girls compared to boys, and the inverse relationship between transportation support and PA. Future studies can expand on this research through the use of real-time methodologies, such as ecological momentary assessment (EMA), to provide important insights into the proximal social and physical contexts that influence youth PA and sedentary behaviors (e.g., physical location, social company) as they occur in real time.[293,294] Objective measures of underserved youth's neighborhood environment would also help provide comprehensive assessments of key neighborhood characteristics (e.g., presence of litter) and PA-related resources.[171,292] In addition to this, it would be important for future studies to examine differences between parent-reported support and youth-perceived support as they relate to accelerometer-measured PA outcomes. This is important, as there is a degree of malleability with respect to perceptions of PA-based social relationships. For example, parents may believe they are supporting their child to be physically active. However, if the child does not perceive this, then the influence on PA behavior may vary.[156,160,295] Therefore, examining discrepancies between youth's perceived availability of support versus actual support received, will offer insight into a potential pathway for the promotion of PA in underserved youth.

Conclusions

This study contributes to the limited research on the moderating roles of parent-perceived neighborhood environment and child BMI percentile in the association between parental transportation support and accelerometer-measured youth activity. Consistent with the socioecological model, youth PA behavior appeared to depend on interacting effects across levels of influence. The neighborhood environment, more than parental support, appears to have greater potential to support specific types of activity (MVPA, MVPA bouts, PA volume). These findings imply that community policies that target changes in the quality of the social and physical environment may be needed to maximize PA behaviors among underserved preadolescents living in less PA-supportive neighborhoods.

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APPENDIX A: R CODE USED TO PROCESS RAW ACCELEROMETER DATA USING GGIR PACKAGE

```
Library(GGIR)
Print(load_params())
g.shell.GGIR(
                #=================================================
                # General parameters
                #=================================================
                mode=c(1,2,3,4,5) ,
                datadir="C:/Child_PA_Data/T1" , outputdir="C:/PA_Results_T1" , idloc = 1 ,
                #=================================================
                # Part 1 parameters:
                #=================================================
                windowsizes=c(5,900,3600) ,
                do.cal = TRUE ,
                do.enmo = TRUE,
                acc.metric=" ENMO",
                #=================================================
                # Part 2 parameters:
                #=================================================
                strategy = 1,
                ndayswindow = 7 ,
                hrs.del.start = 1 ,
                hrs.del.end = 1 ,
                maxdur = 9 ,
                max_calendar_days = 9 ,
                includedaycrit = 16 ,
                qwindow=c(0,6,18,24) ,
                mpvathreshold=c(150) ,
                ilevels=c(50,100,150,200,250) ,
                boutcriter = 0.8 ,
                bout.metric = 1 ,
                excludefirstlast =FALSE ,
                print(load_params( )$params_phyact) ,
                #=================================================
                # Part 3 and 4 parameters:
                #=================================================
                def.noc.sleep =c(1) ,
                includenightcrit = 12 ,
                criterror = 4 ,
                do.visual = FALSE,
                #=================================================
                # Part 5 parameters:
                #=================================================
                threshold.lig =c(50) ,
                threshold.mod =c(150) ,
                threshold.vig =c(500) ,
                boutcriter.in =0.9 ,
                boutcriter.lig =0.8 ,
                boutcriter.mvpa =0.8 ,
                boutdur.in =c(10,20,30) ,
                boutdur.lig =c(1,5,10) ,
                boutdur.mvpa =c(1,5,10) ,
                timewindow = c("MM","WW") ,
                #=================================================
                # Report generation
                #=================================================
                do.report=c(2,4,5) ,
                visualreport=TRUE)
```

APPENDIX B: SUPPLEMENTAL TABLES AND FIGURE

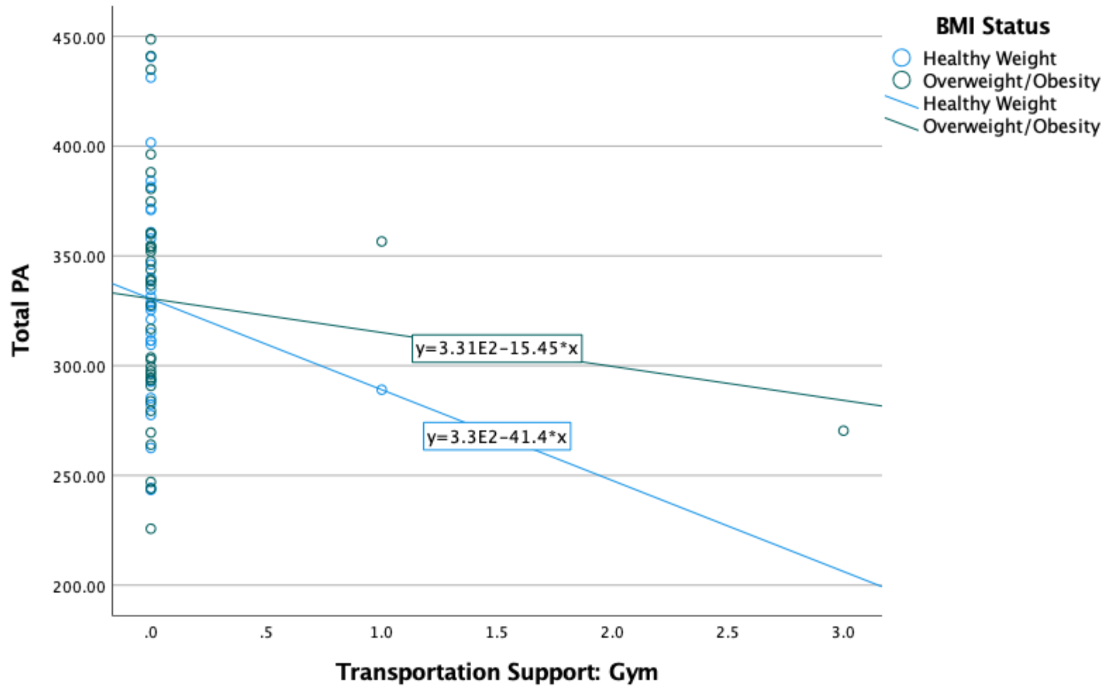

Figure 11: Main moderation analyses examining child BMI-for-age-and-sex percentile as a moderating variable in the relationship between transportation support (frequency of transportation to gym for PA) and total child PA (mean mins/day).

Table 23: Unadjusted Differences in Child Activity by Age, Sex, and Weight Status Categories

	Age		Sex		Weight Status	
	6-9 years (n=33)	10-12 years (n=35)	Male (n=30)	Female (n=38)	Healthy (n=31)	OW/OB (n=37)
	M ± SD	M ± SD	M ± SD	M ± SD	M ± SD	M ± SD
ST	**572.70 ± 76.81****	**621.49 ± 42.70**	598.87 ± 71.52	596.97 ± 62.12	595.61 ± 68.63	599.65 ± 64.46
Total PA	**342.05 ± 53.86***	**317.13 ± 46.44**	324.13 ± 44.57	333.24 ± 56.40	329.62 ± 48.73	328.89 ± 54.12
Light PA	230.40 ± 32.76	222.05 ± 34.62	229.74 ± 24.61	223.23 ± 39.60	221.45 ± 32.40	230.00 ± 34.79
MVPA	**111.65 ± 30.38***	**95.07 ± 28.16**	**94.39 ± 25.31***	**110.01 ± 32.25**	108.16 ± 33.29	98.89 ± 27.10
$MVPA^{1\text{-}5mbts}$	**24.02 ± 10.57****	**20.27 ± 8.07**	**20.80 ± 8.40***	**25.72 ± 10.54**	25.37 ± 11.93	22.02 ± 7.64
$MVPA^{5\text{-}10mbts}$	5.99 ± 4.59	4.45 ± 3.85	**3.74 ± 3.19***	**6.36 ± 4.68**	6.05 ± 4.91	4.49 ± 3.56
$MVPA^{10mbts}$	8.25 ± 8.15	9.58 ± 13.47	**4.81 ± 6.24****	**12.19 ± 13.03**	**12.81 ± 14.21***	**5.69 ± 6.26**
PA Volume	**79.91± 19.45****	**66.81 ± 16.43**	**66.87 ± 14.54****	**78.15 ± 20.75**	**78.20 ± 20.65***	**68.96 ± 16.63**

*$p \leq .05$; **$p < .01$
ST= Sedentary time.

Table 24: Univariate Tests from Factorial MANOVA

Source	$F_{1,60}$	p	Partial η^2
Corrected Model			
Sedentary Time	1.564	.164	.154
Total PA	.856	.546	.091
Light PA	.776	.610	.083
MVPA	2.250	.042	.208
$MVPA^{1\text{-}5mbts}$	3.464	.004	.288
$MVPA^{5\text{-}10mbts}$	3.126	.007	.267
$MVPA^{10mbts}$	4.843	<.001	.361
PA Volume	3.911	.001	.313
Intercept			
Sedentary Time	5584.418	<.001	.989
Total PA	2594.286	<.001	.977
Light PA	2829.681	<.001	.979
MVPA	831.663	<.001	.933
$MVPA^{1\text{-}5mbts}$	447.675	<.001	.882
$MVPA^{5\text{-}10mbts}$	110.545	<.001	.648
$MVPA^{10mbts}$	48.052	<.001	.445
PA Volume	1222.239	<.001	.953
Age			
Sedentary Time	**9.054**	**.004**	**.131**
Total PA	3.623	.062	.057
Light PA	.657	.421	.011
MVPA	6.215	.015	.094
$MVPA^{1\text{-}5mbts}$	**11.116**	**.001**	**.156**
$MVPA^{5\text{-}10mbts}$	3.531	.065	.056
$MVPA^{10mbts}$	.000	.995	.000
PA Volume	**11.711**	**.001**	**.163**
Sex			
Sedentary Time	.028	.868	.000
Total PA	.464	.498	.008
Light PA	.818	.370	.013
MVPA	5.417	.023	.083
$MVPA^{1\text{-}5mbts}$	6.633	.012	.100
$MVPA^{5\text{-}10mbts}$	**9.445**	**.003**	**.136**
$MVPA^{10mbts}$	**9.698**	**.003**	**.139**
PA Volume	**7.994**	**.006**	**.118**
Weight			
Sedentary Time	.038	.845	.001
Total PA	.005	.945	.000
Light PA	.852	.360	.014
MVPA	.968	.329	.016
$MVPA^{1\text{-}5mbts}$	1.566	.216	.025
$MVPA^{5\text{-}10mbts}$	1.624	.207	.026
$MVPA^{10mbts}$	4.597	.036	.071
PA Volume	3.135	.082	.050
Age x Sex			
Sedentary Time	.019	.891	.000
Total PA	.031	.862	.001
Light PA	.217	.643	.004
MVPA	.773	.383	.013
$MVPA^{1\text{-}5mbts}$	1.634	.206	.027
$MVPA^{5\text{-}10mbts}$	1.736	.193	.028
$MVPA^{10mbts}$	.436	.512	.007
PA Volume	.432	.513	.007

Table 24: Univariate Tests from Factorial MANOVA, Continued

Source	$F_{1,60}$	p	Partial η^2
Age x Weight			
Sedentary Time	.299	.587	.005
Total PA	1.051	.309	.017
Light PA	2.012	.161	.032
MVPA	.027	.871	.000
$MVPA^{1-5mbts}$	2.135	.149	.034
$MVPA^{5-10mbts}$	2.575	.114	.041
$MVPA^{10mbts}$	1.276	.263	.021
PA Volume	.014	.907	.000
Sex x Weight			
Sedentary Time	.347	.558	.006
Total PA	.096	.758	.002
Light PA	.536	.467	.009
MVPA	2.084	.154	.034
$MVPA^{1-5mbts}$	2.707	.105	.043
$MVPA^{5-10mbts}$	4.377	.041	.068
$MVPA^{10mbts}$	**9.878**	**.003**	**.141**
PA Volume	3.315	.074	.052
Age x Sex x Weight			
Sedentary Time	.393	.533	.007
Total PA	.123	.727	.002
Light PA	.016	.899	.000
MVPA	.236	.629	.004
$MVPA^{1-5mbts}$	.111	.740	.002
$MVPA^{5-10mbts}$	.155	.695	.003
$MVPA^{10mbts}$	3.053	.086	.048
PA Volume	.573	.452	.009

[a] R^2= .154 (Adjusted R^2= .056); [b] R^2= .091 (Adjusted R^2= -.015); [c] R^2= .083 (Adjusted R^2= -.024); [d] R^2= .208 (Adjusted R^2 = .116); [e] R^2= .288 (Adjusted R^2 = .205); [f] R^2= .267 (Adjusted R^2 = .182); [g] R^2= .361 (Adjusted R^2 = .287); [h] R^2= .313 (Adjusted R^2 = .233).

Table 25: GENEActiv Studies with Youth

Study	Country	Age (y)	*N*	Cut Points	Metric	Sampling Frequency	Wrist
Antczak et al.[214]	Australia	7-11	1,059	Hildebrand	ENMOZ (mg)	87.5 Hz, 5s	ND
Antczak et al.[23]	Australia	7-11	2,745	Hildebrand	ENMONZ (mg)	87.5 Hz, 5s	ND
Bianchim et al.[266]	UK	11 -12	63	Troiano	ENMO (mg)	100 Hz, 5s	L & R
Boddy et al.[205]	UK	10-1	108	Hildebrand	ENMO (mg)	100 Hz, 1s	L
Caillaud et al.[58]	Australia	10-12	83	N/S	N/S	60 Hz, 3s	ND
Da Silva et al.[285]	Brazil	N/S	3,379	N/S	N/S	N/S	N/S
Da Silva et al.[216]	Brazil	7	514	N/S	N/S	85.7 Hz	ND
Díaz et al.[43]	Australia	10-13	61	Phillips	N/S	60 Hz, 1s	ND
Diazand & Yacef[59]	Australia	10-13	61	Phillips	SVM (g)	60 Hz, 1s	ND
Duncan et al.[297]	UK	8-11	30	METs	SVM (g)	80 Hz, 1s	D & ND
Fairclough et al.[206]	UK	9-10	129	Hildebrand	ENMO (mg)	100 Hz, 1s	ND
Fraysse et al.[51]	Australia	10-12	1,261	Phillips	SVM (g)	50 Hz, 60s	ND
Greier et al.[296]	Austria	13-14	36	Schaeffer	ENMO (mg)	10 Hz, 10s	ND
Hildebrand et al.[221]	Norway	7-11	30	N/A	ENMO (mg)	60 Hz, 1s	ND
Hildebrand et al.[207]	Norway	7-11	30	N/A	ENMO (mg)	60 Hz, 1s	ND
Hurter et al.[208]	UK	9-10	27	N/A	ENMO (mg)	100 Hz, 1s	ND
Keane et al.[75]	Ireland	8-11	826	Phillips	SVM (g)	100 Hz	ND
Lacoste et al.[239]	Canada	11	91	Hildebrand	ENMO (mg)	85.7 Hz, 60s	D
Phillips et al.[211]	UK	8-14	44	N/A	SVM (g)	80 Hz, 1s	L & R
Beltran-Valls et al.[54]	Spain	13	189	Phillips	SVM (g)	100 Hz, 1s	N/S
Ricardo et al.[263]	Brazil	6	109	Hildebrand	ENMO (mg)	85.7 Hz, 5s	ND
Rowlands et al.[233]	UK	11-14	1,734	Hildebrand	ENMO (mg)	100 Hz, 5s	ND
Rowlands et al.[46]	UK	11-14	1,669	Hildebrand	ENMO (mg)	100 Hz, 5s	ND
Rowlands et al.[47]	Australia & UK	9-12	238	Various	ENMO (mg)	85.7 Hz, 1s, 5s	ND
Rowlands et al.[209]	Australia	10-12	58	Phillips	GENEActiv (g.s)	85.7 Hz, 1s	ND
Sanders et al.[81]	USA	13-18	930	Hildebrand	ENMO (mg)	30 Hz, 60s	ND
Schaefer et al.[213]	USA	6-11	47	N/A	SVM (g)	75 Hz, 1s	ND
Scott et al.[212]	Australia	13-14	89	Phillips	ENMO (mg)	100 Hz, 15s	ND
van Loo et al.[262]	Australia	5-12	57	Hildebrand	ENMO (mg)	100 Hz, 1s	ND

Abbreviations: ND= Non-dominant wrist; D= Dominant wrist; L= Left wrist; R= Right wrist; N/S= Not specified; N/A= Not applicable.